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EDITORIAL.

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The Technical Education of the Mechanical Engineer.—Amongst the requirements of knowledge by the mechanical engineer, under which title is meant he who should undertake the direction of mechanical construction, not the least important is that he should be thoroughly informed in the capability of the handicraft of the workman. The knowledge of the physical properties of bodies, the mathematical propositions of "applied mechanics," the principles and theory of machinery, the construction, form and adaptation of parts in various machines themselves, with the functions they accomplish, can be acquired, to a great degree, by study; but the capabilities of the manipulations of the workshop or work bench will yet remain a mystery, to be unraveled mainly by experience and observation.

In a general sense in the history of mankind, the question of education, or its methods, is not a new one. Each generation, for itself,

must be taught and must learn, precisely what was learned by the preceding one; and the race in life of the young man will have commenced just when that of his father did. Possibly, sometimes a small increment of knowledge has been gained, and civilization, in its strict meaning of aggregation of people in cities, has taught some one generation lessons in social demands or developments. Education will have followed, and through a series of generations the children will have commenced at a new standpoint, and a new progress in the arts and sciences has been attained. In the arts, this education of the artisan has generally been traditional—from father to son—from master to apprentice; and when, by turbulence and war, the peace-loving and comfortable citizen has been despoiled of his luxuries and comforts, by those who have not known enough to create them for themselves; the unrecorded knowledge has been, for a time, lost; to be acquired again, "under protection of sword." Frequently, the conquerors have protected and employed the workmen, in more or less enslaved conditions; but, with the absence or uncertainty of a free reward, the arts have languished, and have almost, if not entirely, perished—carrying with the loss, the civilization which originally engendered them, and extending the ruin to the victors themselves. A more stable condition of society, where the soldier has not been the ruler, has, in modern times, guarded and fostered the arts and all derived learning; and the last three or four centuries, whose record we have, or are acquiring, has shown a development and growth of the arts and sciences, in unexampled rapidity and magnitude.

The past hundred years alone have witnessed, as seen in the amazing retrospect, the wonderful substitution of machinery for handicraft—of mechanical performance for skilled labor. This has occurred progressively, in the three generations of human life and work which embrace the century, in a kind of geometrical progression for any successive divisions of this period of time.

The apprentice of one hundred years since, acquired by experience the teachings of his master, but applied his labor not wholly to the production of the finished article of trade, but in part to the production of machines which were substituted for his hand tools and hand labor. The grown workman, who was fifteen years later the personator of supposed apprentice, imparted his traditions and acquirements to a new apprentice, who, by the introduction of machinery, was no

longer called upon to exercise all the skill, care or thought, that his teacher had been called to employ, because the *machine* had supplemented his tools; another succession and another followed, each time has the machine gained on hand labor, until now the ability of the mechanic consists more in the use of the machine than of the hand. With this progress of mechanism has followed manufacturing, and much of the teaching of the later mechanics has become in the use of special machines, confined to distinct processes, to the nearly complete neglect of handicraft or artisan skill. Manufactories and machines have called into existence a new class of skilled workmen, who shall have learned how to make available, and possess the ability to bring into novel or repeated practice, the acquisitions in mechanical skill of all kinds; and these men are our mechanical engineers.

The distinguished men in the field of mechanical engineering of to-day, have grown into these positions. The most of their elementary learning has been derived in the workshop, and from the workman, by the traditional method, and their education has been attained in the experience of failure and success which attends new efforts. The more work a man does, the more mistakes he will make; long years of practice have evolved *types* of machines, each detail of which, is an especial result from the labor and intelligence of individual mechanics, and the knowledge of the accomplishment or its methods, yet unrecorded or described, exists only in some directing mind whose capability to apply them constitutes the engineering faculty. The patent records, old and new, cover a small, very small part of the mechanical development of the century, so small that it can almost be said, with truth, that no valuable machine, process or apparatus now is, or ever has been covered by any valid or strictly equitable patent claim—so small that these records are never read either as the total of history, or as a complete exposition of any one appliance in mechanism. Descriptive literature is equally at fault in the completeness and practical application of the knowledge which has been gathered in its pages, so that there remains as the only reliable basis of action by the mechanical engineer, only his *appreciation of the capabilities* of materials, both as materials and in manipulation; the latter being either performed by the workman or by the "*machine-tool.*"

It is easy to see how this knowledge has been acquired by the present holders of it, but it is obvious that the same path is not open

to their successors. The large workshops and manufactories have divided labor, in following out their legitimate end of profitable production, until the mechanic in their employment has become the "operative" or overseer of the operations of a machine, with the least of manual or intelligent effort left to humanity. This operative can scarcely be called a workman, and it is very sure that nothing except the possession of the highest mechanical ability will allow him to become an engineer, even if chance gives him an opportunity to develop the ability; and at all events it is sure that the mechanical engineer of the future who shall rival foreign and other competitors in accomplishments, will have learned in another school. Not only is the *operative* of the special machine thus debarred from attainment of knowledge, but the *workman* in the machine shops, at the smiths' fires, in the pattern room, or the foundry, all in their constancy of labor at their divided branches of industry, are precluded from acquiring general knowledge. Possibly the foreman of a gang of men, or the draughtsman in the office wherein the work is originated, may have the desirable opportunity to witness labor and accomplishment, but the derivation of foremen and of draughtsmen is ceasing to be from the ranks of the operative workman.

Given the educational basis which is now recognized as needful for a civil or mechanical engineer, how is the young man to become a foreman or a draughtsman, in the completion of his course of instruction? Given the ability or executive direction which causes a young man to be selected from out of the group of working operatives to act as foreman; or the mechanical perception which has elevated the youth from the bench to the office desk, how is he to acquire the knowledge of books requisite for him to become a directing engineer? These are the questions to be answered.

There are those who lay great stress upon the value of the old institution of apprenticeship, the return to which is in some way to be supposed to restore the capability of acquirement of engineering knowledge to the present generation, on a footing similar to that possessed by former ones. This view has been advocated very recently to such effect, that a special act of the Pennsylvania legislature was passed at the last session (of 1876), offering extraordinary legal safeguards, and immunities from responsibility, unknown to the old common law, to manufacturers employing apprentices. If these apprentices shall be really taught as of old in the entire art and mystery of their

several occupations, in all that the *master* knows, shall be cared for, bodily and mentally and above all morally, during their apprenticeship, so that when they become journeymen, they will (if they have been diligent youths) be fitted to become masters themselves—not mere laborers—then this law may bear the promise of satisfactory return. But when the obligations of equitable apprenticeship upon the masters, here asserted are admitted, it appears almost certain that the results of this apprentice act, will scarcely fill the expectations of some of its advocates and friends.

In every grade of workshop in England, and especially in the engineers' shops (as the machine shops are there denominated), as well as in the offices of the civil engineers, student apprentices or articled pupils are employed. With regard to the former of these, there are many reasons why a similar practice has not been and will not be followed in this country. The first of these reasons is the comparative absence in England of that destructive rivalry in mechanical business which exists in America. The rates for labor, and the estimated value of the mineral in that country, have been so low, and the application of machinery so much in advance, (at least until recent years of the century) that England has led the world for a market. The established product of an English workshop, has at all times possessed what might be called a good will. Few of them will purposely rival, in the same way, another in the production of what is the regular manufacture of the one, and but the exceptional demand upon the other; and purchasers are yet more chary in the acceptance of work from inexperienced makers. A man can be generous who has an abundance; he can be just, where he is sure of just dealing in return. Perhaps the condition of abundance has more relevance to the subject under discussion than that of justice. Not many American manufacturers would accept educated, clear headed, intelligent young men as student apprentices, to learn from their workmen, their machines and their processes, the art and mystery of their business. Beside this the condition of the student apprentices amongst the workman in one of our shops, may be regarded as too anomalous to the habits of the average American workman or foreman, to be supposable in actuality. The second method for obtaining practical experience—that of the articled pupil—suffices in the office of the engineer, but is far from satisfactory as the method to learn the value of the workshop manipulations to the pupil. In this country, at this

time, there are no articled pupils, and even students in engineers' offices are rarely to be found.

Neither a return to the system of apprentices and masters, nor the adoption of the method of pupilage in an office, presents the least prospect of affording the education of the business engineer in the future.

The simple question follows, why should not a boy be taught practical mechanics in the school? and this question carries with it its own reply. There is no reason why constructive mechanism should not go hand in hand with applied (mathematical) mechanics, or why manipulation should not be taught at the same time with the properties of materials in the lessons of the school. In accordance with these views, within the past few years, several of our American colleges have established classes and professorships in conjunction with their courses in technical learning. Amongst these, the Sheffield School at Yale College, New Haven, Conn.; the Cornell University at Utica, N.Y.; the Stevens Institute at Hoboken, N. J.; the Free Institute at Worcester, Mass., are prominent examples. Other technical schools have, in different degrees, pursued the handicraft culture of their scholars.

But in thoroughness of teaching, and especially in exhibition of attained success, there is now presented to the admiration of all mechanics, at the Centennial Exhibition, a special example from a foreign land, which should induce emulation. The exhibit made by the Imperial Technical Schools of St. Petersburg and Moscow, demonstrates the feasibility of so educating pupils, that when they pass out from the doors of their school, they will have become at once scholars in their learning from books, and proficients as educated workmen in the varied branches of the workshop. These young men on leaving college are quite as able to demand work as journeymen, as the average of mechanics when out of their time, for they will have—must have—performed by unaided effort, such feats in workmanship, within limited times for accomplishment, as none but skilled workmen can do. The demonstration of the Russian schools is, that this practical instruction can be given in the fullest range and quality, not only without interfering with, but positively to the advancement of, other indispensable professional studies. From such an example there should not be the least hesitancy in following the same course in the technical education of the American mechanical engineer.

Dry Dock.—For many years the commerce of Philadelphia has felt the great want of proper facilities for docking large vessels for repairs, there being no private docks except two small floating ones, quite too small to accommodate vessels engaged in our foreign trade.

The floating dock at the old navy yard was sometimes allowed to be used for merchant vessels, but the formalities and uncertainties attending its use, the remoteness from ship yards and shops made its use expensive and unsatisfactory.

To meet this want Messrs. Wm. Cramp & Sons determined to construct at their ship yard on the Delaware, at the foot of Hanover Street, a stationary Dry Dock of sufficient size to take in the largest vessels that enter this port.

The water of the river at this point being fresh, there is no danger to a wooden structure from the teredo or shipworm, and therefore, in order to reduce the first cost it was determined to construct it entirely of wood. The plan adopted was that invented by Mr. J. E. Simpson, who was also the constructor.

The dimensions are as follows: length from head to gate, when in position, 430 feet; length of keel blocks, 420 feet; width at bottom amidships, 45 feet; width at top amidships, 111 feet; width at gate, 70 feet; depth, 26 feet; depth below high tide, 23 feet.

After making the necessary excavations the foundation was formed by driving 12-inch iron-shod oak piles about 10 feet into the disintegrated gneiss rock which underlies that locality. These piles are placed about 4 feet apart in both directions, over the entire bottom, except along the centre under the keel blocks, where there are four touching each other in each row. To the top of the piles are fastened 12-inch timbers running across the width, and on these is laid the floor of 3-inch plank.

To form the sloping sides, piles were driven perpendicularly, in rows corresponding to those in the bottom, and cut off to a line conforming to the proper inclination. On the top of the piles were secured timbers running longitudinally, and to these were framed and fastened other timbers running down the slope, and fastened at the foot to the bottom timbers. To these sloping timbers were fastened the planking of the sides, consisting of timbers, the cross section of which is a right angle triangle, with one of the acute angles cut away for a few inches, and so placed as to form steps of about eight inches rise and the same tread. Several rows of sheet piling were driven

across under the dock to prevent the water from the river finding its way underneath, and tending to float it.

The gate is an iron boat of sufficient length and depth to fill the gateway. The keel, stem and stern post project evenly about six inches, and are made to fit in grooves in the bottom and sides of the gateway. These grooves are lined on their inner sides with rubber, so that when the pressure comes against the gate a water-tight joint is formed.

The gate has tanks to be filled with water to sink it to its position, and is provided with pumps to exhaust them, and also valves to admit water to the dock when it is to be filled.

The dock is now in daily use and will prove to be a great advantage to the shipping interests of the city.

Removal of the Obstruction at Hell Gate.—Common report anticipates the explosion which is to destroy the piers in the mine at Hell Gate channel as of probable occurrence on the 5th of September ensuing, and there seems to be a general expectation that the event will be a startling one. But unless some error is made in the estimation of the power of the explosive agents, the chances are that it will prove one of the most quiet and tame transactions ever witnessed where the resulting effect will not have been commensurate to but one-tenth or one-twentieth of the present anticipated one in magnitude. As an engineering exploit the success will be measured in some considerable part by the absence of violent disturbance. If the destruction of the piers and the decadence of the shell of rock now covering the excavated ruins, could be as quietly performed before the spectators on the shore and out of the water, as an eclipse of the moon is to persons inside of a closed up room, the success of the operation would be undoubted. It is especially desirable that the debris should not be removed from its present locality, but simply deposited on the floor of the present excavations, from whence it can be removed without interrupting navigation. Unless some enthusiastic spectator fires a Chinese cracker, the Quaker meeting of removing the obstruction is likely to pass off in relative quietness, and the disturbance of water, except the escape of a volume of gas for a moment, will, in all probability, be less marked than that which occurs at Hell Gate at any half tide from the meeting of the currents.

NEW METHOD OF IMPROVING HARBORS.

[From *Engineering News*, August, 12, 1876.]

For many years it has been a serious question how to preserve the harbors on our Gulf coast. The conditions involved are in many respects similar to those on our northern lakes, the chief thing to be guarded against, being the closing of the mouth of the harbor or bay by the sand swept along by the littoral current. Of course the device usually adopted in such cases is some form of the parallel jetty, which, checking the current along the shore left the space between the jetties to be scoured out by the action of the tides and local currents or to be dredged where these were absent.

The storms of the Gulf are often quite violent, and structures of more than ordinary strength are required. All the ordinary forms of timber crib-work or pile jetties are precluded from the fact that they are soon destroyed by the teredo navalis, no method of preserving timber from their destructive ravages having proved efficient. Breakwaters or piers made of stone are not practicable from the great distance it would be necessary to transport the stone. Concrete blocks are quite expensive and only warranted when there are immense commercial interests to subserve, which condition does not exist at present on the Gulf coast. It is very doubtful, from the ease with which sand finds its way through the Port Said breakwater, if loose blocks of Concrete would be efficient, or if they would not entirely settle out of sight, as the Gulf sand is quite finely comminuted and well worn. At any rate some less expensive method must be found or else the number of Gulf harbors must be comparatively limited.

In 1874 experiments were commenced on a new method of construction at Galveston which is destined to be the most important Commercial City of the Gulf and to whom the preservation of her harbor is of vital importance.

We have watched these experiments with great interest and are pleased to record that they have met with such success as to warrant the inference that the harbor question of the Gulf States is already solved, and by a method of construction withal, quite economical.

The method adopted is by gabions* placed in rows so as to form a training wall or jetty. The final form and method of construction

*The mode of protecting the gabions from the teredo does not seem to be clearly stated.—Note by Ed. F. I. J.

adopted for these gabions is as follows: A bottom of two inch planks is first laid down, this bottom being 12 ft. long and six ft. wide, the ends being semicircular. In holes bored about the edges of this bottom pine stakes six feet high are placed. Between these stakes wicker-work of cane or willow is interwoven, and on the top is placed a plank covering similar to the bottom. The whole is securely nailed and two ¾ inch iron bolts pass from top to bottom, binding all solidly together. The bottom is covered with a layer of concrete and the exterior is plastered over with two coats of cement plaster with takes a firm hold on the wattling, and the whole left to dry for two weeks.

In the line of the proposed jetty, guide piles are driven 24 ft. apart, and the gabions mounted on float boats and towed out, and launched in position by the guide piles. Through holes left in the top they are filled with sand by a sand pump. A fascine made of brush from the cane, is placed between the gabions in order to prevent the current which may rush through the crack left, and excavate large holes. Usually in front of the row of gabions a mat of brush held down by concrete blocks is placed and is found to prevent effectually any tendency of the current to undermine. If great danger is apprehended from this cause, two or three gabions may be formed into a spur at right angles to the main line and these spurs placed at intervals effectually prevent undermining. Should one row of gabions prove inefficient, as soon as the sand fills in back of them, a second tier may be erected back of and parallel to the first, and even a third may be required.

These gabions have withstood the severest storms of the Gulf without damage, and the preliminary works at Galveston, although comparatively limited in extent, have resulted in a much increased depth on the bar, and a notable protection of the end of Galveston Island. The cost of the gabions in place, with the present experience in construction, is about $5.00 per lineal foot. The estimate for Galveston Harbor was 37,000 running feet of jetty, two tier high, and 20,000 of spur-jetty, one tier high, to cost $489,740.

This is much cheaper than equivalent work can be done for on our lakes. Similar gabions here would be utterly destroyed by ice. The cement might be omitted as there is no danger from the teredo, but it would not hold sand and hence would be useless.

WISNER & STRONG.

BALANCED SLIDE VALVE.

Fig. 1

Fig. 2

Fig. 3

WISNER & STRONG,

BALANCED SLIDE VALVE.

Fig. 1

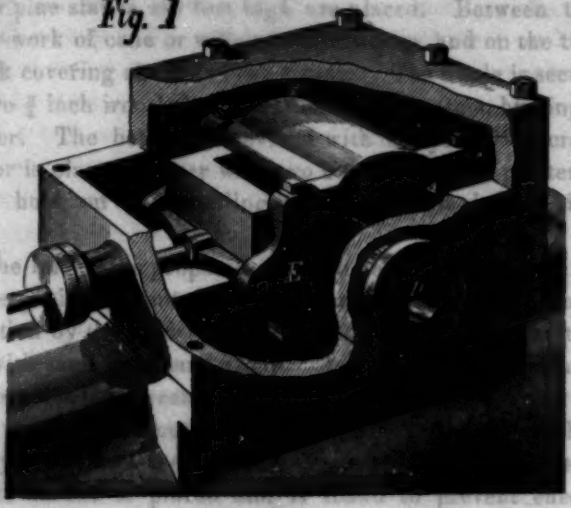


Fig. 2

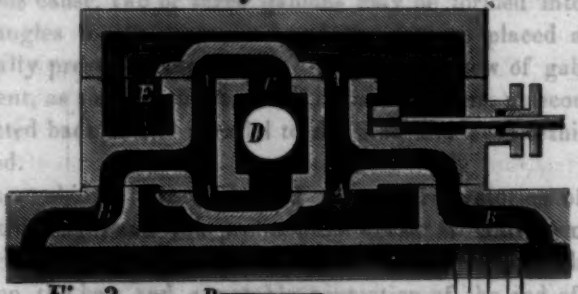
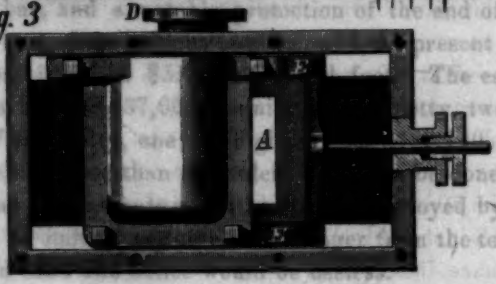


Fig. 3



Improved Balance Slide Valve.—Wisner & Strong, Pittston, Pa. Centennial Exhibition, Machinery Hall, south side, sec. B, column 72.—The accompanying wood cuts show a slide valve arrangement, offering some points of superiority over the saddle plate, or relief method of effecting the balance. The section Fig. 2, gives a distinct view of the way proposed to be used, which is a pair of valves covering seats on opposite faces of a separate channel piece, this channel piece in this case being the main steam chest casting. Channel ways at the end of the separate piece (on one face), come in line with those of the cylinder, so that the steam passages to the cylinder lead from double valve seats in the same way, only through a slightly lengthened course, as from an ordinary seat cast upon the cylinder. The two valves which rest upon these faces are held apart by distance pieces at their sides, and are thus made to balance each other. The outer valve of the two is secured to the distance blocks by bolts having springs under the locked nuts, so that it is as free to lift off its face in event of water in the cylinder, as the ordinary slide valve. The gain in the removal, of the cooling effect of the exhaust from the side of the cylinder—where the exhaust passage is commonly formed—nearly, if not quite, compensates for the extra length of passage which the arrangement demands; while the double valve gives all the advantage of a grid-iron valve, with abundance of room in the chest for an efficient lap, which conditions are nearly unattainable with a double-ported valve, moved by a single eccentric, for ordinary length of cylinders. The balancing is nearly perfect, and the valves have been found to be at first quite as tight as any single valves; and after two years' running have shown no signs of wear, preserving their original tightness.

These slide valves will work, with the least of power, with certainty of action at all times; expansion or contraction not affecting the bearing on the faces, the relief being equally good at starting the engine, to what it is when fully at work, with steam at high temperature. Locomotives or hoisting engines with such valves can be reversed, under any pressure of steam, with perfect ease and safety. An Engine at the Centennial is now running a line of shafting and working under 50 to 55 pounds pressure of steam. This engine has its cylinder 16 inches in diameter by 30 inches stroke, and the valves have 150 square inches of covering surface. These valves are operated by means of a valve-rod 3-16ths of an inch in diameter, in lieu

of the usual size of about 1¼ inches diameter. It is scarcely necessary to call attention to the economy of original construction and finish, of this plan for balanced valves, and the facility of access if repair should ever be required; but these are obviously not the least of its merits.

FUEL AND ITS USE.

By Prof. H. Fritz, Zurich.

[From *the Journal of Applied Science*, August 1, 1876.]

Although frequent attempts have been made to render the use of fuel as advantageous as possible, the results are far from satisfactory, as only part of the heating power is utilized. The difference between theoretical and effective heating power for various sorts of fuel may be seen by the following table, which gives the number of pounds of water evaporated by one pound of fuel.

Fuel.	Heating Power.		
	Theoretical.	In Steam Boilers.	In Open Boilers.
Petroleum	16·80	10—14	.....
Anthracite	12·46	.....	.....
Coal	11·51	5·2—8	5·2
Charcoal	10·77	6—6·75	3·7
Coke	9—10·8	5—8	.....
Brown coal	7·7	2·2—5·5	1·5—2·3
Peat	5·5—7·4	2·5—5	1·7—2·3
Wood	4·3—5·6	2·5—3·75	1·85—2·1
Straw	3·0	1·86—1·92	.....

As regards the heating of steam boilers, Mr. Thompson found, by a series of experiments, that, on an average, only forty-seven per cent. of the theoretical heating power of the fuel is utilized, the remainder being lost through imperfect combustion, radiation, and other causes. Since portable engines have been arranged for straw burning, this fuel has become of great importance for agricultural purposes. Trials at the Vienna Exhibition proved that one pound of straw is capable of evaporating from 1·81 lb. to 1·97 lb. of water into steam of seventy pounds pressure and 305°6 Fahr. Compared with Thompson's figures for other fuels, straw would seem to give more

work than even coal; but the trials in Vienna were made with Exhibition engines, and under the most favorable circumstances. Amongst the other caloric engines tried up to the present time, only those working with hot air, exploding gas, and exploding vapor of petroleum have proved of practical use. The following table shows the comparative merits of different systems:—

Air Engines.	Pounds of Fuel per Hour, and H. P.	Relation between Effective and Theoretical Work of Fuel.
Belou	3·3—4·84	6·0—4·1
Leawitt	6	3·5
Lehmann	10·12	1·9
Leauberau	9·9—13·15	2·0—1·4
Ericsson	11—16·5	1·8—1·2
Gas Engines.	**Quantity of Gas reduced to Coal in lbs.**	
Otto and Langen	3·96—6	5·0—3·5
Hugon	9·9	2·0
Lenoir	9·9—12	2·0—1·8
Petroleum Engine.	**Petroleum in lbs.**	
Hock	1·65—2·86	8·4—4·6

Comparing the different steam engines with these motors, it is found that as regards work they are nearly equal, or rather, the duty varies for steam engines and other caloric motors almost between the same limits. To show this, the following table is arranged according to the work of the different motors:—

	Per cent.
Small high-pressure engine without expansion	1·8
Air engine, Ericsson	1·8
" Leaubereau	1·8
" Lehmann	1·9
Gas engine, Lenoir	2 0
" Hugon	2·0
Portable steam engine	2·8
High-pressure steam engine with expansion	3·0
Air engine, Leawitt	3·5
" Belou	4·1

Condensing engine with expansion	4·5
Gas engine, Otto and Langen	5·0*
Petroleum engine, Hock	8·4
Large steam engine, best make	9·0

Although, according to this table, the work of high pressure steam engines is less than that of gas or air engines, the cost of fuel for the latter still exceeds that for steam engines from 2·5 to 5 times, a circumstance which explains the fact that, notwithstanding the many advantages of air or gas engines, they are not able to replace the ordinary high pressure steam engine.

Book Notice.

TREATISE ON THE MECHANICAL THEORY OF HEAT.—R. S. McCulloch, C.E., Professor of Mechanics, Washington and Lee University, Va. 12mo, 288 pp. D. Van Nostrand, New York, 1876.

It would be difficult to find a parallel example of so excellent, thorough, and exact a text book, as completely wanting in inductive arrangement; while at the same time it is not known where to look for any corresponding presentation of the dynamics of heat of equal clearness or accuracy. If, however, it is assumed that the book is a résumé of lessons—that it has followed, and accompanied courses of physics and practical mechanics, in which the several propositions have originated, then the mathematical demonstrations in some order of sequence, will have become invaluable aids to the learner, and this recapitulation in the groups chosen, will be highly advantageous.

In the preface of the work the author speaks of the retrogression "of scientific, as well as classical, education in this country, and superficially is the fashion of the day," by way of apology for the use of the concise language of modern mathematics. Without denying the decline of Greek scholarship—Is not the publication of this work in this country at all an indication of progress? The first page of notation, which is not that of the "fluxional calculus," is evidence of the growth of English mathematical science during the past fifty years.

* This rate of actual economic effect for the Otto and Langen engine is delusive in some regards. First, there are obvious limits of size for the Otto and Langen principle of action when reduced to working practice, so that the relative economy would be affected (impaired) materially when an engine develops any large quantity of power, say above 8 to 10 horse power, and second, the Otto and Langen engine is especially economical in the performance of irregular labor, in which regard it appears to present striking advantages over any other engine known.

The English reports of this engine also place it higher in the scale than is shown on this table.—See JOURNAL OF THE FRANKLIN INSTITUTE, vol. C, p. 262. (Note by ED. F. I. J.)

May there not be a scientific one-sidedness quite as objectionable as an unscientific "superficiality?" For the mathematician to insist that the mechanical theory of heat is purely a question of thermo-dynamic functions, is probably as untenable ground, as the proposition that the science can be investigated or understood without them. The facts must exist and should be stated, previous to the investigation into their causes and effects.

The mechanical theory of heat can be clearly given. It is the theory that the motion of a body may be changed into vibrations of the molecules which form that body—that these vibrations constitute the condition which is called heat—that heat pervades, and is incident to, all material substances—that heat transfers, with a tendency to equality of vibratory power, from one body to another (although the value of a vibration in one body differs from that in another)—whence generally, the putting in motion of any body is always attendant with the abstraction of definite quantity of heat, (molecular vibration); and the dispersion of a corresponding amount of heat, attends the coming of a body to a state of rest.

Of this statement of the mechanical theory of heat, the molecular vibration is of course hypothesis—no direct experiment can show it—but it certainly fills the requirement of accounting for the preservation of continuous motion in the universe; and by analogies with acoustic vibrations, which can be exhibited and have been studied, many, if not all, of the phenomena of heat can be reduced to mathematical laws. The absolute generation of heat by the application of force—by the retarded motion of the body, is, however, an established fact in physics, and was first announced by Rumford, 1790-8, and has since been determined with acceptable accuracy by Joule, 1843-9; and although older mathematicians, beginning with Huyghen, 1690, and going through a list of distinguished names (amongst which Newton's appears as an opponent to the theory) down to 1850, advocated a vibrating theory for light and heat, yet it was not until 1849 that Rankine and Clausius and Thomson enunciated, as an accompaniment to Rumford's convertibility of force to heat, the theory of thermo-dynamics.

Perhaps there is not in all of English scientific literature a better use of language than that which, in Rankine's Steam Engines and Prime Movers, commences Chap. 1, of Part III, "of relations amongst the phenomena of heat." Beginning with the most elementary statement, the perspicuity of words has left no uncertainty or inaccuracy for the most critical or advanced student, and step by step the reader is led to the results which Prof. McCulloch has expressed in another order, and somewhat more at length. In point of fact, Prof. McCulloch's book is the acknowledged production of the study of Rankine, Clausius, Thomson and Hirn, with reminiscenses of Carnot, Clapyron, Fourier, Fresnel, Regnault and others; and in this regard it is the book for the professor rather than for the pupil.

Still, one cannot help remarking what an admirable book would have been produced, if the experimental and mechanical foundation had been established in an inductive order.

The want of assertion of some such basis leaves in many places an opening to question the mathematical results. The writer of this notice for instance, is by no means prepared to accept Hirn's conclusions and resulting adabiatic curve. A careful examination of Rankine will show that he did not place the most implicit reliance on the indicator in his efforts to show the absolute useful effect. He uses the diagram in the form of an indicator, and with all propriety, but never a card of actual engine performance. There are too many contingencies. The indicator is really an admirable instrument for the steam engineer, or a mechanic, in showing place of valves, leakages of valves or piston etc., etc., but it demands great skill to make it exhibit these conditions. The instrument itself, when of the most delicate make is open to criticism; and when jacketed cylinders are employed, the distortion of steam line for the low pressure is, with the inevitable leakage of the piston, out of all possible bounds of assumable error. There are some other propositions, which may be open to doubt. The phenomena exhibited by water when heated above the boiling point, and the spheroidal (so-called) condition of water—both of these had another explanation given in the pages of our JOURNAL.*

In one regard beyond all others, this excellent book is noteworthy. While it is a treatise on the most positive of all branches of study, an exposition of the reasoning faculties only, it is prefaced and concluded in an acknowledgment of the insufficiency of mere human understanding; and the averment that the most profound researches of the human intellect, are but contemplations of fragments of the infinite wisdom which rules the universe; and it points from the revelations of nature, to those which have been given to us more directly and positively.

Cornish Pumping Engine at Providence, R. I.—The large engine (one of the largest in the country) which has been erected at the principal water station for this city, on the Pettaconset river, has commenced to run in a highly satisfactory manner. It is pumping all the water needed for the present supply of the city, a quantity within 4 million gallons each day, moving quietly at about seven and a half strokes per minute—equal to 7½ millions of gallons in 24 hours, with the steam following the piston 15 inches (11 feet stroke). The reported duty is 95 millions of pounds of water lifted one foot per one hundred pounds of coal supplied to the boilers.

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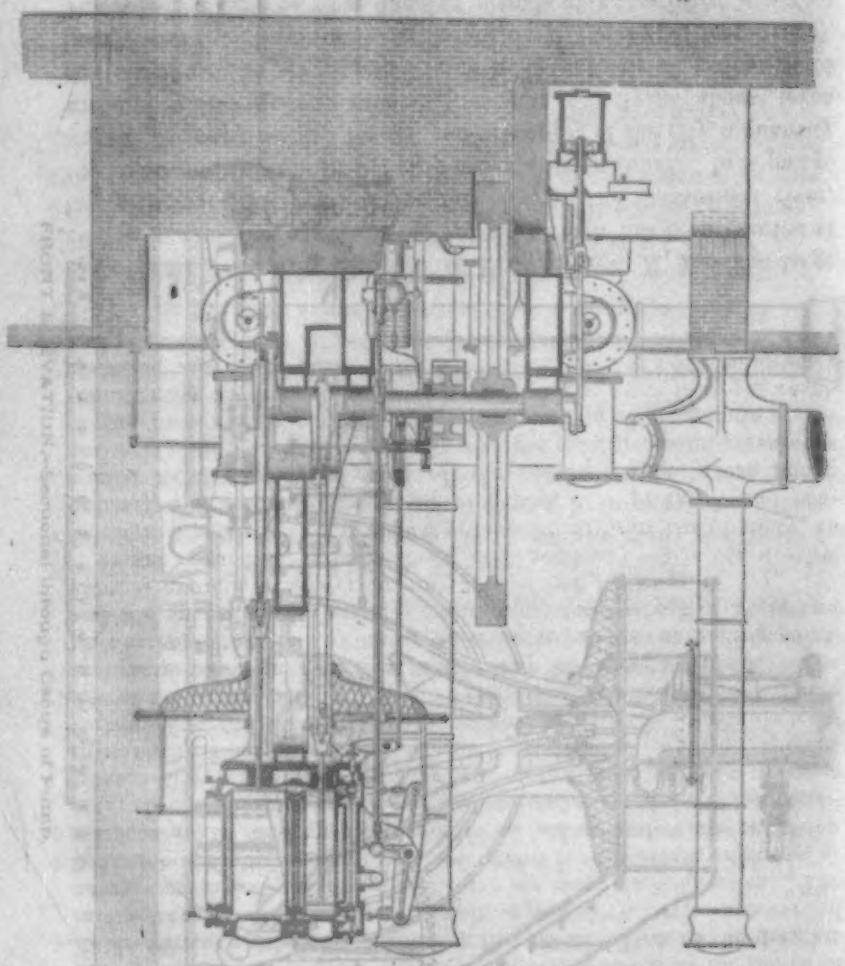
* See present volume, page 86, *et seq.*

CROSS SECTIONAL ELEVATION.



PROVIDENCE, R. I. WATER-WORKS.

FOR THE

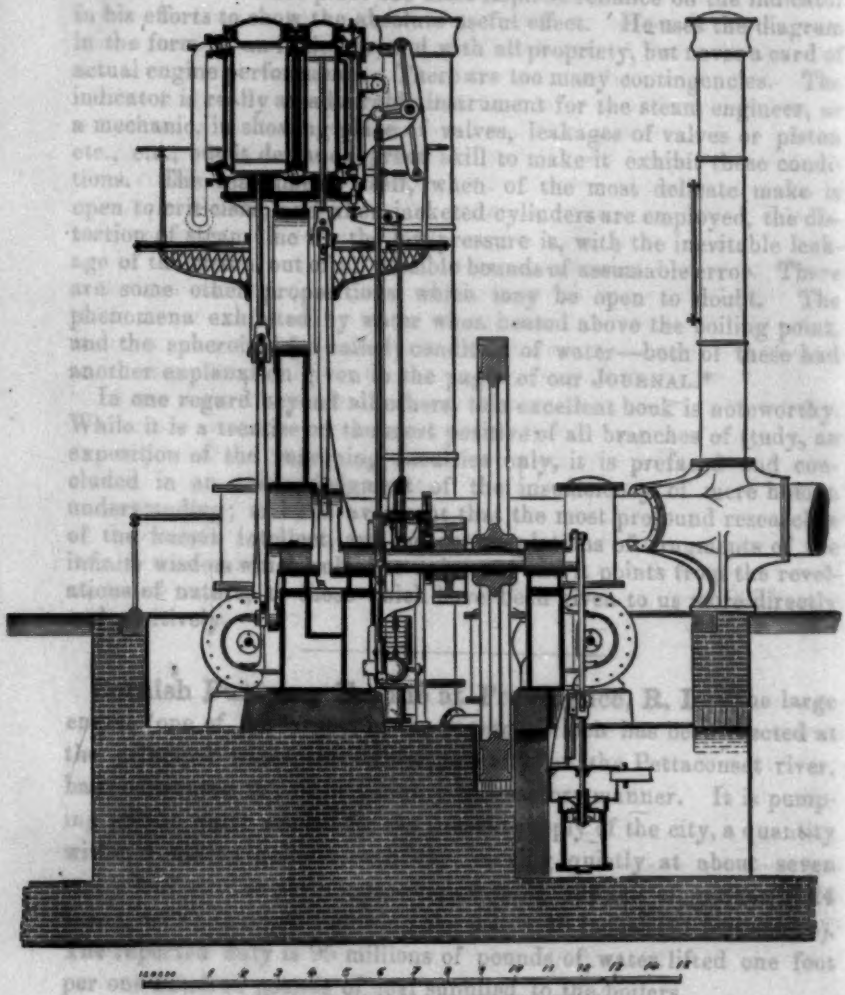
PUMPING ENGINE

Journal of the Franklin Institute, Vol. CII.

PUMPING ENGINE

FOR THE

PROVIDENCE, R. I. WATER-WORKS.

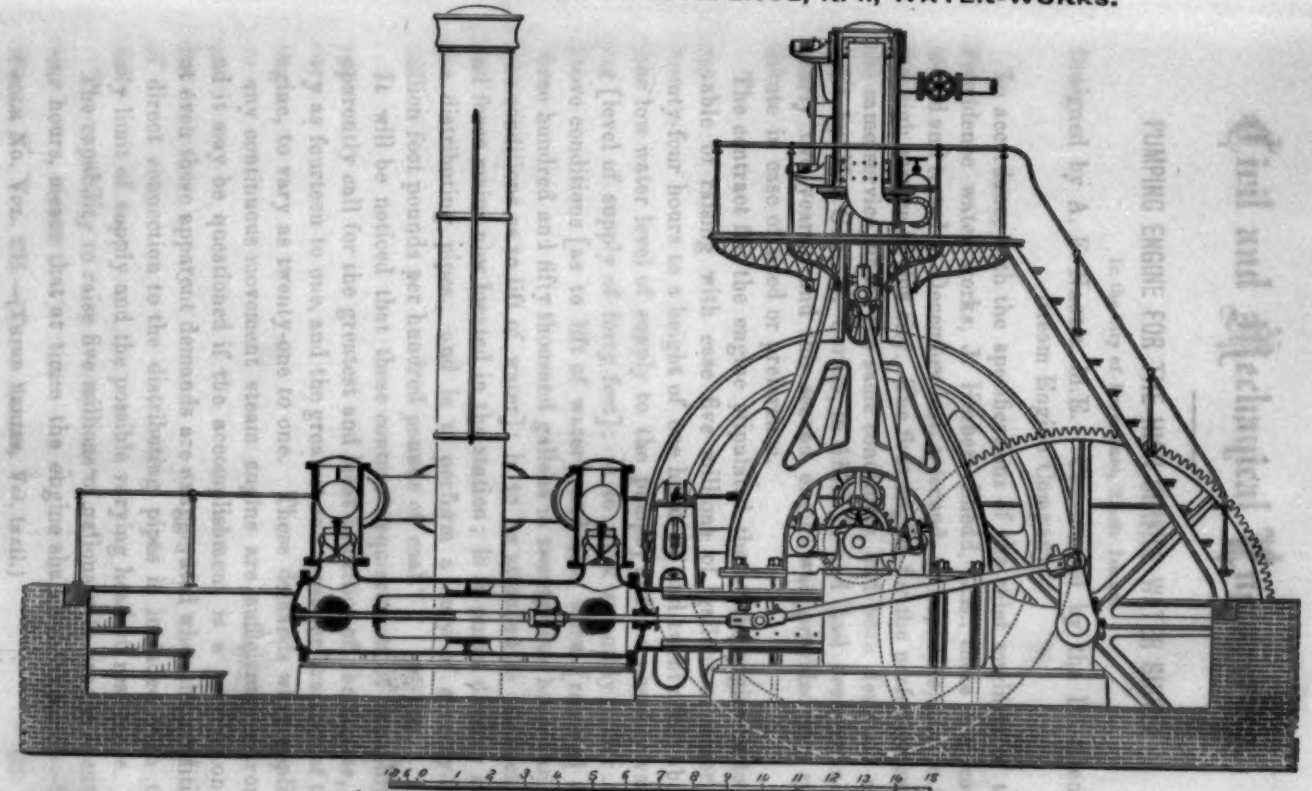


CROSS SECTIONAL ELEVATION.

A. F. NAGLE.

PUMPING ENGINE FOR THE PROVIDENCE, R. I., WATER-WORKS.

PUMPING ENGINE FOR THE PROVIDENCE, R. I., WATER-WORKS.



A. F. NAGLE.

FRONT ELEVATION.—Sectional through Centre of Pump.

PUMPING ENGINE FOR THE PROVIDENCE, R. I., WATER-WORKS.

FRONT ELEVATION.—Section through Centre of Pump.

A, A, Area.

Civil and Mechanical Engineering.

PUMPING ENGINE FOR THE HIGH SERVICE WATER SUPPLY

In the City of Providence, Rhode Island.

Designed by A. F. NAGLE, M.E. Constructed by the Providence Steam Engine Company.

In accordance with the specifications of the chief engineer of the Providence water works, J. Herbert Shedd, C.E., there was completed and tested in December last, a second, or duplicate, engine for the high service in this city. The first engine for the performance of the same service, under the same conditions, had been designed and built by Mr. Geo. H. Corliss, in 1872-'3, and had been running nearly two years; and this second engine was provided as a substitute in case of need or preference.

The contract for the engine stipulated that "the engine is to be capable of raising with ease five millions of gallons of water in twenty-four hours to a height of one hundred and twenty feet above [the low water level of supply to the pumps] under a possibly varying [level of supply of forty feet]; is to work smoothly under the above conditions [as to lift of water], and also when [raising] but three hundred and fifty thousand gallons in twenty-four hours [under like conditions as to lift of water]; is to be attached to the suction and force mains now located in the station; is to pump directly into the distributing pipes; and is to perform a duty of seventy-five million foot pounds per hundred pounds of coal."

It will be noticed that these contract requirements of capability, apparently call for the greatest and least velocities of the engine, to vary as fourteen to one, and the greatest and least performance of the engine, to vary as twenty-one to one. These demands when applied to any continuous movement steam engine are sufficiently onerous, and it may be questioned if the accomplishment is a possible one; but even these apparent demands are exaggerated when the condition of direct connection to the distributing pipes is included with the daily limit of supply and the possible varying head of resistance.

The capability to raise five millions of gallons with ease in twenty-four hours, means that at times the engine shall run at a rate—for

some minutes—which would supply, if continued, six millions in twenty-four hours, while the delivery of three hundred and fifty thousand gallons in the distributing service in any twenty-four hours could hardly call for a speed of engine, at midnight, for instance, that would exceed the rate of ninety thousand gallons, if continued the whole time. These figures give the variation of speed of engine between the greatest and least requirements as nearly seventy to one; and the variation of greatest and least *performance* as one hundred to one.

Without entering into the question of the possibility of accomplishment, in this notice, it will only be said that the engine did not fulfil the specifications (neither did the Corliss engine) to the letter of the contract. But by means of a relief valve, a quantity (not stated) of water, which, it may be assumed, was considerably in excess of the three hundred and fifty thousand gallons in the twenty-four hours, was permitted to escape from the distributing pipes, (under the resistance of flow through the aperture of this valve, and discharge into the supply mains), to be pumped over. In this manner the necessary constancy of resistance was made to accompanying extreme variations of demand, so that when the requirement was exceedingly small, the regular work provided by the "relief valve" would be sufficient to keep the engine in motion with comparative smoothness.

This evasion of the terms of the contract being allowed, the testimony of the experts (Chas. Hermany, C.E., J. B. Francis, C.E., and Prof. Chauncey Whitaker) shows that the engine would command the exigencies of the service for which it was intended, which really are the maximum supply of five millions of gallons in twenty-four hours, with a minimum supply of whatever may be abstracted from the water pipes at any time. And this irregular demand was met even to the maintenance of pressure when the fire hydrants of the district were put in use suddenly and without communication with those employed about and running the engine.

The usual stipulations as to quality of material, workmanship, strength of parts, and changes of plan, delivery of material, advances of money during construction, protection from liens on work or material, etc., follow in due course in the contract.

With these clauses, there is one which has become usual with some engineers, whereby the contractor is made to defend the city, its officers and agents, against all patent claims or demands, under a

bond of indemnity. If this condition bears the restricted sense of subjecting the contractor to make payment for the use of anything which may be patented in the construction of the work only, limiting the obligation to the profit he may derive as a constructor from such use, as against the use of well known unpatented devices, it is open to no reasonable objection; but if it means that the contractor is to bargain to make himself liable for the value of all or any patented arrangements, whereof the city of Providence may have had the advantage or profit in use, and which patented arrangements the city officers have procured to be made for the city, then the condition is onerous and unfair in the extreme. Under this last rendering the unfortunate contractor would be required to defend, knight errant fashion, against all comers, while the city authorities can foster, encourage or default in the litigation, wherein he may be liable to serious loss, without having the least valuable consideration for his liability.

The engine was to have a duty, as tested by a board of three experts, of "at least seventy-five millions of foot pounds per one hundred pounds of coal, when delivering two million gallons in twenty-four hours against a head of one hundred feet." "The conditions of the trial are to be similar to those adopted in the trial of the Lynn Pumping Engine, in December, 1873."

The boilers and appurtenances, together with the engine foundation, were embraced in the terms of proposals, and were part of the contract.

The price for the whole was fifty-four thousand dollars, conditioned on performance as above, with a requirement to remove the engine and all, if the stipulations of the contract were not met.

The essential feature in the Lynn trial was the establishment of some value of fuel by the use of selected and picked anthracite coal, that would yield about 10 per cent. only of ashes, or 90 per cent. of combustibles.

The test of this engine has not been yet reported in detail, but a summary or result is stated by the experts: "The engine pumped at the rate of a little more than two million (2,000,000) gallons per twenty-four hours by weir measurement, and made a duty of 84,637,245 foot pounds per hundred pounds of coal consumed.

"This work and duty were obtained during a continuous run of fifty-six hours, fifty-one (51) of which were selected by omitting some

hours at the beginning, and some at the end of the trial, for which fifty-one hours the calculation is made; all the coal put into the furnace was charged to the engine, and no deduction made for clinkers, ashes or cinders." *

On the basis of the report of the experts the engine was accepted, and a settlement made with the city, subject to the guarantee of the contract of "the strength as well as the quality of the materials and workmanship of all the parts, and the making good on the part of the contractor, at his cost, all outlays or injuries caused by defects in the same during first twelve months of working the engine," a responsibility which (under the circumstances of the engine, with its duplicate to be operated if it is thought proper) may not be relieved for the next twelve years.

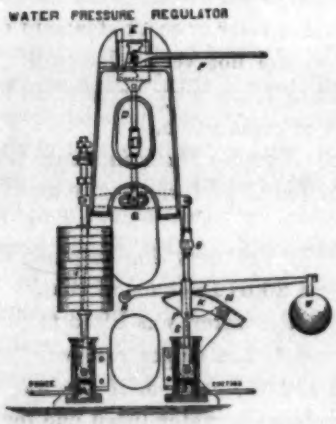
The engine, which has been found to conform to these stringent requirements, is shown in elevation and cross section on the accompanying cuts. It is of the vertical, double over head cylinder, compound type, usual for propeller engines, with a double crank shaft, and opposite connected cranks. The main shaft is led off on the high pressure side, and carries a fly wheel of considerable weight, and has behind the back bearing a half-stroke crank, which gives motion to the piston of the air pump, and preserves the vacuum in a jet condenser. On the main shaft is a pinion which communicates motion to the pumps through a gear wheel upon a second crank shaft. The pinion and gear bear the relation to each other of one to five. There are two horizontal pumps, one on each side of the bedplate of the vertical engine, driven by right angle cranks at the rate of one stroke of the two pumps to each five strokes of the engine. The pump valves are double beat, there being one suction and one delivery valve at each end of each pump. The high pressure cylinder is eleven inches, and the low pressure one is nineteen inches in diameter; the stroke is three and a half feet. Both cylinders are steam jacketed by live steam.

The admission and emission of steam is effected by three separate gridiron slide valves at each end of the two cylinders, which are moved on their seats by sliding cams, having a vibratory action. These cams are worked, although not directly, by a single eccentric; and by the motion given to the valves; the first valve admits steam for the high pressure cylinder; the second valve serves for the exhaust valve

* If the whole time had been taken, the result would have been a little *more* favorable.

for the high pressure and an admission valve for the low pressure cylinder; while the third valve is the exhaust valve from the low pressure cylinder to the condenser. The flow of steam in the high pressure cylinder being controlled by a governor, which regulates the motion of an auxiliary cut-off valve, on the back of the steam valve.

The automatic arrangement for adapting the speed of the engine to the varying requirements and conditions of the service, consists of two cylinders, into one of which water is admitted from the suction side, and into the other from the delivery side. The varying pressures of water in these cylinders, resulting from the increase or decrease of the supply on the one hand, as compared with that in the delivery on the other—so acts on the fulcrum of the connecting lever between the two cylinders as to operate the cut-off, and adapt the supply of steam and the consequent speed of the engines to the then existing circumstances. This governing apparatus has not operated quite as successfully as could be wished, as the effective power for performance of the work of moving the position of the cut-off cams given at the instant of increase of pressure from 119 to 120 feet head of water, is scarcely large enough to be available, and the friction resistance of the plungers is too great a disturbance to the delicacy of action of the pressure.



The fly-wheel is thirteen feet in diameter and weighs eleven tons. As the speed of the fly-wheel is five times as great as that of the pump shaft, the effective value of momentum in preserving the uniform velocity of the engine, is twenty-five times that which it otherwise would have been.

The pumps are seventeen inches in diameter, and have a stroke of four feet. The consequent displacement of the two pumps is 271,440 gallons each twenty-four hours; whenever a double stroke (or revolution) of the *pair* of pumps is made per minute. The requisite *average* speed for the specified quantities to be delivered was, therefore (without allowing for loss by leakage), eighteen and two-tenths revolutions for the greatest, and one and three-tenths revolutions of

the pump shaft for the least quantities, per minute. The corresponding velocities of the engine were ninety-one revolutions, and six and a half revolutions per minute. The experts limit their report as to the smooth running clause to "It did run smoothly while performing this work," *i. e.* 2,000,000 gallons, or thirty-six and four-tenths revolutions of the engine per minute.

On the whole this engine of the high service at Providence can be confidently accepted as one of the most satisfactory solutions of the problem of the direct water supply to a distributing service, without the accompaniment of reservoir or stand pipe.

The boilers provided with the engine were two in number, each with about twenty square feet of grate. They are of the ordinary fire box, flue-and-top tubular type, of American river or coast steamers of small size. As might be supposed, they are not very self-acting to meet vicissitudes of requirement of 100 to 1, nor very economical in evaporative effect of fuel for slow rates of combustion.

A statement made in the Providence *Evening Bulletin*, Aug. 3d, is the authority for the following comparison of performance in actual service between the two engines.

For the week ending July 23d, 1875, the first engine pumped 3,320,055 gallons of water, and consumed 26,610 pounds of coal.

∴ This performance is equivalent, if the water was lifted to full pressure from the least level of water supply (an empty reservoir, or 120 feet water-column pressure), to 12,482,000 duty, or if the water was lifted only 80 feet high, 8,322,000 duty, or water lifted one foot high by 100 lbs. of coal.

For the four weeks ending the same date, the same engine pumped 13,999,095 gallons of water, and consumed 110,262 pounds of coal.

∴ This performance is equivalent to 12,693,000 duty for the high lift or 8,642,000 duty for the low lift.

The corresponding time of year and date—July 23d, 1876—the second engine—that under discussion in this article—has pumped for the week 4,851,600 gallons of water, and consumed 6,400 pounds of coal.

∴ A performance which reduces to 75,806,000 maximum, or 50,535,000 minimum duty.

For the four weeks ending July 23d, the second engine is stated to have pumped 19,792 000 gallons, and consumed 25,495 lbs. of coal.

∴ A performance which reduces to 77,613,000 greatest, or 51,742,000 least, duty.

How much was pumped to waste through the relief valves was not stated, but possibly it was an equal proportion on the two engines; the difference of quantity of water pumped is accounted for by the increase of water supply to the district. On the four weeks' service the last engine appears to be about 6·11 times more efficient than the first.

Errata.—Insert on page 123, vol. CII, at end of line 18, "motion of the," so that the clause of the sentence will read "that the motion of the point of attachment to the main valve-rod ceases."

MEMORANDA RELATING TO TWO 90-FEET CHIMNEYS FOR SIEMENS' HEATING FURNACES AT THE EDGAR THOMSON STEEL WORKS.*

By P. Barnes, Resident Engineer.

[Extracted from the *Engineering and Mining Journal*, June, 1876.]

Exact accounts have been kept of the cost of these chimneys, and it may be a matter of some possible interest that the plans and details of cost should be laid before the Institute. The statement of cost herewith submitted does not give minute particulars of the weights or quantities of material used, although these are noted upon the company's books.

Reference being made to the accompanying drawings, it will be seen that each chimney has an external shell of sheet iron, which rests on an iron base plate, and is thus anchored to the masonry foundation.

They are identical except in the depth of the concrete formation. One of them (North) had to be put in the bottom of a slight valley on the premises, while the other (South) stood on higher and solid ground. Flues were led into the chimney base from two directions, one being large enough for two furnaces.

The base was carried eight feet above the general level of the yard, partly for appearance sake, and partly to keep venturesome boys from climbing up the ladder on the outside.

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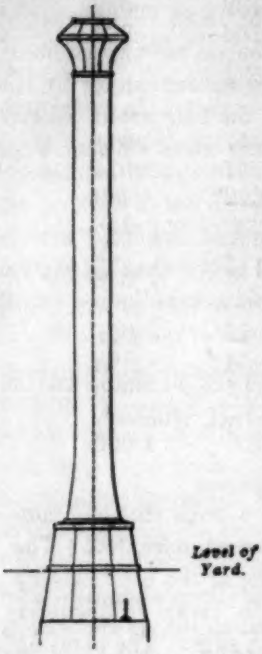
* A paper read before the American Institute of Mining Engineers, at the Cleveland Meeting, October, 1875.

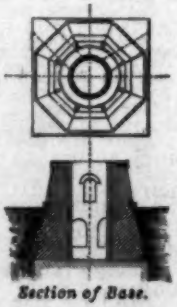
The whole base from the level of the flues was made of red brick grouted in cement, chiefly for the purpose of utilizing a large lot of soft brick that had accumulated at the works. The anchor bolts were hung in place before the brickwork was commenced—the washers resting upon the concrete—so that the total weight of the brickwork is utilized in securing the stability of the chimney shell. At the level of the ground in the yard, a belt course, and upon the top of the base, a coping of sandstone were laid; and upon the latter the iron base plate, in four pieces, was bedded in cement.



Elevation of Base and Shaft.

A side flue lined with firebrick was put in, leading, above the belt course, into the central flue, both to give access to the interior, and to build a fire in, when needed to secure a more perfect draft. The shell was made in 4 feet courses, the lower ones being tapered outward to give a broader base upon the plate. The first course was made of 5-16 inch iron, the next four of 3-16 inch iron, and the remaining upper part of $\frac{1}{4}$ inch iron. A light ladder was put upon the outside, and carried entirely over the top. The finish at the top was made of No. 22 galvanized iron, and painted inside and out.

The interior lining was made of common red brick, laid in lime mortar, and it is 4 inches thick, except at the bottom, where it is thicker, to suit the enlarged diameter of the shell.


Section of Base.

The shell was put together complete while lying on its side upon the ground, and hoisted into place in one piece. This was found, even for so light a weight, to be more troublesome than was anticipated, although no real difficulty was experienced. The cost of erection, however, was slightly greater than really need have been incurred.

All that can thus far be said of the actual performance of these chimneys is that they give a tremendous draft, and that as yet they have not been at all shaken by the wind.

COST OF SOUTH CHIMNEY.

		per cent. of cost.
Excavation	$132	·032
Concrete-stone and labor	264	·064
Cut stone " "	267	·065
Cement—total used	230	·056
Lime " "	53	·013
Sand " "	57	·014
Anchor bolts	57	·014
Castings	242	·059
Red brick	629	·153
Bricklaying, foundation	242	·059
" lining	197	·048
Sheet iron shells	1,190	·292
Paint	29	·007
Labor of erection, etc.	444	·108
Teaming	103	·025
	$4,136	1·009

DISCUSSION.

Mr. Metcalf said that he had recently built a brick chimney containing 143,000 brick, and that the cost was less than $3,000. The brickwork was 31 in. thick at the base and 13 in. at the top. Every three feet, flat iron rings, 2 in. by $\frac{1}{8}$ in., and 18 in. larger in diameter than the interior of the flue, were inserted, set on edge. The painting of iron stacks is a serious objection to them, since the paint must be repeatedly renewed. He had found the best and cheapest paint to be common soot with the light oil from the refineries, costing about ten cents a gallon. It does not contain acid which, when tar is used, attacks the iron perceptibly.

Mr. Pearse said that the reason iron chimneys were first built was to avoid the cracking of brick chimneys when driven hard. The Pennsylvania R.R. had built a chimney shaped like a double star, the points acting as buttresses. He preferred the iron chimney with square base plate, to get a leverage at the corners, and said that, having built several, the first used in this country, he had gradually reduced, with safety and success, both the thickness of metal and lining—the metal to $\frac{1}{4}$ in. at bottom and $\frac{1}{8}$ in. at top, and the lining to 4 in. firebrick at bottom, then red brick, and 2 $\frac{1}{2}$ in. red brick at top. The foundation could be made without cut or ashlar blocks, using bricks and cement under the bedplate, and a chimney like this was built for $3,800, at Harrisburg, in 1872.

Mr. F. Firmstone had always thought brick chimneys were both better and cheaper than iron ones, but never supposed before that the difference in cost was so much in their favor. They had just finished the shell of a brick chimney at Glendon, 105 feet high and 6 feet in diameter, which would cost much less than the one described by Mr. Barnes.

This chimney rests on a concrete foundation 15 feet 6 inches in diameter. The base is 13 feet in diameter, 9 feet high, and 4 bricks (3 feet) thick. At 9 feet high, it is diminished by offsets to 11 feet 6 inches diameter, and 2½ bricks (1 foot 10½ inches) thick. Above this it is built with a batter of one-quarter inch per foot to the top, diminishing in thickness by three internal offsets, each of half a brick to one brick (9 inches) in the top section. A double row of hoop iron, in pieces about 2 feet long, was laid in the bed joints at every eighth course, one row close to the outside, and one close to the inside of the shell. It is to be lined to a height of 69 feet, with firebrick 4½ inches thick. It was begun August 17, 1875, and finished October 8, in 44 working days, by 2 bricklayers and 5 laborers.

The cost, exclusive of scaffolding* and mortar, of which no account was kept, has been as below.

58,400 bricks at $10·25 per M. . . .	$598 60
2 bricklayers 44 days at $3 each . .	264 00
5 laborers 44 days at $1.10 . . .	242 00
10 bundles hoop iron	35 00
Cast iron cap, 2,280 lb. at 4 ½ c. . .	102 60
	$1,242 20

Suez Canal.—The filling up of the Suez Canal is an event that may now be considered indefinitely postponed. Last year between the two seas, only 52,700 cubic metres of "stuff" were removed, and the canal was navigated with facility by steamers drawing as much as 27 ft., and over 400 ft. in length. The bed of salt which forms the bottom of the Bitter Lakes, is gradually dissolving, so that this portion of the canal is being gradually but steadily improved, and with the increase of vegetation along the banks of the canal, there is a prospect of the production, in a not distant future, of a fertile and populous tract of country out of a sandy waste.

* Note by the Editor F. I. J.—In the construction of this chimney there was not only no necessity for a scaffold, but skilled chimney builders would prefer to work without one.

THE STRENGTH OF BOILER FLUES.

By Prof. W. C. Unwin.

[From London *Engineering*, July 7, 1876.]

Sir.—The strength of boiler flues is a subject of sufficient importance to deserve further attention. Putting on one side at present the formula of Love, there are three formulæ under discussion:

1. Fairbairn's original formula,

$$p = 806{,}300\,\frac{t^{2.19}}{l\,d} \quad . \quad . \quad . \quad . \quad (1)$$

2. An approximate formula given by Fairbairn in a foot-note, which you term the practical form of Fairbairn's rule,

$$p = 806{,}300\,\frac{t^{2}}{l\,d} \quad . \quad . \quad . \quad . \quad (2)$$

3. The same formula with a new coefficient deduced from the experiments by yourself:

$$p = 465{,}314\,\frac{t^{2}}{l\,d} \quad . \quad . \quad . \quad . \quad (3)$$

You do not question, and it is certainly true that Fairbairn's original formula fits his experiments better than any other. But you think it must be abandoned (1) because it is too complicated and difficult to use, (2) because by adopting equation (3) the tendency to use thick plates is discouraged. The first objection may be removed by using a small table of values of $t^{2.19}$ calculated for those thicknesses of plate which are common in practice. The following is such a Table, and with its aid the collapsing pressure can be obtained as easily as the breaking weight of a bar:

t =	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$
$t^{2.19}$ =	·002307	·01053	·02558	·04803	·07829	·1167
t =	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	1
$t^{2.19}$ =	·1636	·2192	·2837	·3573	·5326	1·000

As to the second objection it does not seem to me well to mix up in one formula two entirely distinct classes of considerations. Fairbairn's formula is understood to give the collapsing pressure of flues uninjured by fire. If it is modified it will not give the collapsing pressure accurately, and it will not insure us against the danger of using plates of too great thickness, for it does not prohibit the use of plates of absurdly great thickness. No doubt thick plates are

dangerous, and the practical experience which leads us to avoid their use is best embodied in a separate cautionary rule.

In order that it may be seen in what degree the three rules differ, the following Table has been computed. Any of the numbers in this Table multiplied by $\frac{806,300}{ld}$ gives the collapsing pressure of a flue. The numbers in Column I are proportional to the collapsing pressure by equation (1). Those in Column II to the collapsing pressure by rule (2), and those in Column III to the collapsing pressure by rule (3). The Table extends to all the thicknesses likely to occur in practice.

	I	II	III
t	$t^{2.10}$	t^2	$a\,t^2$
$\frac{1}{16}$	·00231	·00390	·00225
$\frac{1}{8}$	·01053	·01563	·00902
$\frac{3}{16}$	·02558	·03515	·02029
$\frac{1}{4}$	·0480	·0625	·03606
$\frac{5}{16}$	·0783	·0977	·0563
$\frac{3}{8}$	·1167	·1406	·0812
$\frac{7}{16}$	·1636	·1914	·1104
$\frac{1}{2}$	·2192	·2500	·1443
$\frac{9}{16}$	·2836	·3164	·1826
$\frac{5}{8}$	·3573	·3906	·2254
$\frac{3}{4}$	·5326	·5625	·3246
1	1·0000	1·0000	·5771

Taking Fairbairn's rule as the standard equation (2) gives collapsing pressures 70 per cent. too high for tubes $\frac{1}{16}$ in. thick; 20 per cent. too high for $\frac{3}{8}$ in. tubes; and the error diminishes with the increase of thickness up to 1 in.; it then changes sign. Equation (3) gives collapsing pressures nearly right for very thin tubes, but the error for tubes $\frac{3}{8}$ in. thick is 30 per cent., and for tubes 1 in. thick is 42 per cent. The three rules differ so widely that it is not indifferent which is chosen. But if the experiments are relied on, there is no doubt that Fairbairn's original rule is the best. For moderately thick tubes rule (2) is not far from accuracy. For thin tubes, on the other hand, rule (3) is better than (2).

In applying Fairbairn's rule two points should be kept in mind. 1. In all Fairbairn's experiments, with, I think, one exception, there

was a longitudinal tension in the tube due to the mode of fixing, and it is possible that this to some extent influenced the results. 2. Fairbairn's tubes were so riveted and soldered that they were nearly as strong to resist compression at the joints as in the solid tube. This is not always the case with boiler flues. If the longitudinal seams, for instance, have lap joints they will probably give way in certain cases by shearing the rivets. In those cases no doubt the resistance will be altered.

Mr. Wilson has given a calculation of the direct crushing resistance of the tubes, and a similar rule is adopted by the Board of Trade. Without questioning that such a rule may have use as a counsel of caution, it may be pointed out that it is scientifically very defective on these grounds. 1. It ignores the influence of the ends. 2. It ignores the effect of the longitudinal joints. 3. It rests on a very doubtful estimate of the crushing resistance of iron.

The rule really gives the crushing resistance of an infinitely long tube, supposing that in such a tube buckling or collapse could not be prevented. There is no good reason for supposing that the influence of the ends ceases for short tubes, but *a priori* it might be expected that the influence of the ends was greater for short tubes than for moderately long ones. To take an extreme case, a tube 1 in. long must be so completely sustained by the ends that it is difficult to see how fracture could occur. Then if there are riveted joints, it is the crushing resistance of those joints, and not that of the solid plate, which should enter into the calculation. Lastly, Mr. Wilson takes the crushing resistance of wrought iron at 12 tons per square inch, and you have quoted from Rankine 36,000 lb. to 40,000 lb. as the crushing resistance. None of these numbers are very reliable. I have frequently loaded prisms of wrought iron, 1½ diameters in length, with 50, 80, and even 100 tons per square inch. With such pressures the iron is much compressed, but often it is not cracked, and would carry a still greater load. Without, however, adopting these extreme numbers, it would be better to base the calculation on the elastic compressive resistance of wrought iron, which is known to be about 10 tons per square inch, and not on the very imperfectly known ultimate resistance to crushing. There is no reason why, with a passive kind of load, the working stress on a welded flue should not be 5 tons, and that on a lap riveted flue 2 tons or 2½ tons per square inch.

The most remarkable feature of Fairbairn's experiments is undoubtedly the influence of the length on the resistance, and I do not know that any explanation of this singular law has been suggested. There is, however, one coincidence in the experiments which may afford a clue to the reason why the length influences the resistance. If the figures of the collapsed tubes are examined, it will be seen that at the moment of giving way they must have been buckled into a wavy form consisting of curved arcs meeting at points of contrary flexure. They form in fact a series of convex and concave bellies. Now the number of these bellies is related to the ratio of the length to the diameter of the tubes, as the following Table will show. This Table contains the whole of the experiments.

Ratio of Length to Diameter.	Number of Curved Arcs at moment of Collapse.	Ratio of Length to Diameter.	Number of Curved Arcs at moment of collapse.
15	4	5·0	6
15	4	5·0	6
10	4	4·75	6
9·8	4	4·75	6
9·5	4	4·8	6
7·5	4	4·8	6
7·5	4	4·0	4 *
7·5	4	4·0	4 *
5·0	4	3·75	8
5·0	4	3·7	8
5·0	6	3·7	8
5·0	6	3·2	4†
5·0	6	3·0	10
5·0	6	2·5	8

The least possible number of arcs into which the tube can divide is 4, and the number of arcs must be even. Looking at this Table the correspondence between the number of arcs into which the tube divides and the ratio of length to diameter is unmistakable. Connecting this with the known laws of resistance of a long column to longitudinal compression, it is not difficult to see a reason why the shorter tubes, which divide into a greater number of arcs, should have a greater resistance.

If we take a circumferential strip of the flue and treat it as a long column subjected to compression, then the external uniform

* Thick tubes imperfectly collapsed; lap and butt joint.

† Thick tubes slightly collapsed.

pressure p which would produce the waved form is given by the equation

$$p = \frac{1}{6} \frac{\mathrm{E} n^2 t^3}{a^3}$$

where n is the number of arcs of which the waved form is made up. If, then, we can connect n with the diameter, length, and thickness, a partial explanation of the influence of the length would be found.

NOTE BY THE EDITOR F. I. J.—A discussion upon the subject of the law of strength of boiler flues under external pressure, has been carried on in *Engineering* since March last (having proceeded originally from a paper of Mr. Fletcher, the chief engineer of the Manchester Steam Users' Association, read before the Institution of Mechanical Engineers), while the discussion itself has been participated in by Prof. Unwin, as quoted above, by Robt. Wilson, C.E., and by the editor of *Engineering*, with others. To the pages of this valuable paper readers are referred for a full comprehension of the points in issue, with only a few remarks in support of Prof. Unwin's view of the case.

Sir William Fairbairn instituted a very elaborate series of experiments in pursuit of this law, which is published in extended form in his "Useful Information for Engineers." In the course of these experiments he observed with great care the effect of pressure under variations of length of tubes of a given diameter and thickness. Like all experiments with material not perfectly homogeneous, the results were somewhat divergent, but he obtained nineteen experimental examples which were to him satisfactory for giving an average result. He next followed the investigation by tests of tubes of larger diameter and of greater thickness. These tubes were not only open to the same unreliability of result, from imperfection of material, but they were no longer tubes, being riveted flues instead; yet, with the well-known acumen and the mechanical experience of Sir William Fairbairn, it would be difficult for any one to question his judgment in accepting certain values which he actually found in these trials, and in rejecting others. Thus, if his mature consideration led him, with all the conditions of the study fresh in his mind, to adopt experiments 24, 33 and 22 as representing with fairness the best approximation of a flue made from plates to a perfectly cylindrical flue, then

the acceptance of his conclusion will follow in the minds of those who can perceive no defect in the experimental data itself. After getting the data, however, the steps of reduction to rule which may follow are open to question. The extension of the table given by Prof. Unwin above the thickness of $\frac{1}{4}$ an inch is certainly unwarranted. There is no safety in estimated values passing the limits of observation in either direction. Within these limits the experimental errors are definitely established; beyond them, the effect of such errors cannot be anticipated; with small departure beyond limits no serious error can occur; but the attempt to extend a table which is extraordinarily cumulative between 0 and $\frac{1}{4}$ of an inch of thickness to 1 inch, will not give reliable figures.

Fairbairn's resulting empirical formula has the shape of:— $p = A\frac{t^{2.19}}{l\,d}$, where p = ex. pressure in pounds, t = thickness of tube in inches, d = diameter in inches, l = length in feet, and A = a numerical co-efficient determined by the experiments. It is a fair sequence to his experiments on tubes of a given diameter and thickness, that the pressure for collapsing, varied in inverse ratio with the length, but it would seem probable that the variation of pressure for tubes of other diameters and length should have been found to have followed some ratio of the thickness to the diameter, and not inversely as the diameter only. This fact is recognized by Sir Wm. Fairbairn in the attempt to reconcile the divergency for tubes of 12 inch diameter to the general law, although his attribution for reason of discrepancy "to the difficulty of maintaining such thin tubes of large diameter exactly in cylindrical form," cannot be taken as a full statement of the conditions which call for a correction in the form of $-B\frac{d}{t}$ to the general formula. At first sight it would look as if the form $p = A\frac{1}{l}\left(\frac{t^n}{d^m}\right)$ would have been more likely to give the approximate empirical formula, which should have covered a *further extended course of experiments*, and embraced the results with greater completeness. Prof. Unwin's observation, however, that a probable nodal condition accompanied the collapsing (under any ascertained load p), is warranted by the experimental data given by Fairbairn, and is a proper legitimate conclusion based upon materials of supposable homogeneity, and would appear in that formula which would

express the complete solution of the problem. Whatever formula should be adopted, as Prof. Unwin remarks, a table based upon it for practical use will divest the source of the table from any inconvenience, and possess the merit of correctness not belonging to an erroneous though simple rule.

Unfortunately, Fairbairn's experiments refer to a tube whose failure can only occur by passing the limits of crushing strength (which Prof. Unwin properly states, for wrought iron, to be 80 or even 100 tons per square inch), or by want of uniformity of the material; and his results are finally based on the average imperfection of his tubes in this last particular. While the requirement of the engineer is to know what are the limits of strength of flues made from plates riveted up, and subjected at once to the strains of their setting in the boiler, and to external pressure. Further experiments are clearly desirable, in place of arguing as to the construction of Fairbairn's formula with reference to its misapplication to boiler flues.

THE MANUFACTURE OF STEEL AND MODE OF WORKING IT.

By D. Chernoff, Assistant Manager of the Abouchoff Cast Steel Works, near St. Petersburg. Translated by W. Anderson, M. Inst. C.E.

Communication to the Russian Technical Society, 1868.

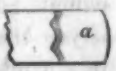
[From *The Engineer*, July 7th, 1876.]

Steel, as generally used in the arts, is a combination of iron and carbon. The purer these elements in steel, the higher are its qualities. The best steel that has ever been made in any age or country is, without question, "boulat" (the sabre steel of the Tartars). The special qualities of boulat, and especially the markings appearing on its surface, have sent many investigators on a wrong scent; all thought to find the extraordinary qualities of this steel in some special mixture. Careful analyses have been made, but, to the surprise of all, nothing has been found competent to explain the presence of the characteristic veining. Inasmuch as the veining of boulat is closely connected with its quality, it was attempted to find substances which, being melted with the steel, would produce the markings required. Steel was melted with various metals, with platinum, silver,

and so on, and veinings were, no doubt, produced; but in the first place, they were far from having the same regularity and beauty, and secondly, as well as chiefly, the steel produced was always inferior to boulat. The peculiarity of the veining of boulat lies also in this, that if you heat a good specimen of the steel with clearly marked veining to a bright red heat, and then allow it to cool, it will be impossible to restore the markings, no matter how long you treat the surfaces with acid. The veining, on the other hand, produced by the mixture of metals never disappears, however much the steel may be heated. But if the piece of boulat, in which the veining has disappeared, be melted again, then, if certain conditions in the cooling of the ingot are observed, the veining appears again, though of a somewhat different design; and in this manner it is possible to produce or annihilate the pattern several times. The investigations of Anosoff have clearly shown that the problem is solved in the purity of the steel, and he has succeeded, as is well known, in producing the very highest qualities of Eastern boulat. On a former occasion I spoke of the observations I had made on the ribbons of dead tint observable on the surfaces of steel guns in the lathe. By means of careful daily records in the forging of the gun ingots, I found that these tints appeared in the boundaries between the hot and the cold portions of the ingot being forged; that is to say, always at those points up to which the ingot was pushed into the furnace. The position and appearance of the strips of dead tint always coincided with the position and form of the limit of heating. If a spot so noted by me was afterwards reheated, then the ribbon of dead tint no longer appeared after turning in the lathe. Besides this, some of these ribbons would disappear as a greater or less thickness of metal was turned off; others penetrated right through the mass of the gun, and never disappeared.

It is further remarkable that although, at times, the transition from the heated to the cold portion of the ingot was so gradual that it was impossible to assign any limit, yet the ribbon of dead tint developed by the turning of the surface of the gun, and corresponding to the above ill-defined limit of heating, was so clearly marked, that it was easy to trace its boundaries with a pencil on the surface of the gun. It must be remarked also that the ribbon has only one well-defined margin, that which was turned towards the cold end of the ingot; the other margin is shaded off imperceptibly into the

normal end of the steel. Wishing to investigate the effects of the steam hammer on the structure of steel, I heated a 4½ inch ingot to a bright red color, and subjected it to two heavy blows of a 5-ton hammer, so that one-third the length was not touched at all, the second third was flattened to 3 in., and the last received two cross blows, under each of which there was a compression of at least 1½ in. The ingot was then left to cool in the open air, and on being broken it was found that the appearance of the structure of each of the three sections remained identical, not only to the naked eye, but to the most careful microscopical examinations.



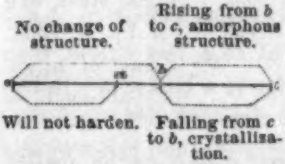
I have also drawn attention to the circumstance that, on one occasion, when experimenting on the influence of the temperature to which steel was heated, on its hardness in tempering, I ordered a smith to heat a piece of steel to dull red, but he, by mistake, heated it bright red. Wishing to rectify the error, I did not at once plunge the steel into water, but let it first cool down to dull red, and then immersed it. Although the steel was of a quality capable of extreme hardness in tempering, the immersion not only did not make it hard, but actually made it sensibly softer. I have recalled the above circumstances, because in connection with many others, they induced me to investigate the influence of temperature on steel, and formed points of departure from my researches. Space will not allow of my describing my experiments in detail. I must content myself with stating the conclusions to which I have arrived. If steel melted in a crucible is constantly kept in violent agitation while cooling, agitation violent enough to keep all its particles in motion, then the cold ingot produced will have a very finely crystallized structure; if, on the other hand, the melted steel is allowed to cool in perfect quiet, then the resulting casting will consist of large, well-developed crystals. The appearance of these crystals, and generally the tendency to crystallize under these circumstances, will depend on the purity of the steel. As I have already stated, the ultimate purity of the steel consists in that of the two component elements, iron and carbon, and that the best steel is composed of only these two elements. With reference to other elements, the presence of which is supposed to influence the quality of steel, it is impossible to avoid mentioning the opinion of Fremy, who considers nitrogen so essential, not only to the formation, but to the very existence of steel, that he has laid down the proposi-

tion that "if nitrogen is taken away from steel it will cease to be steel"—*Comptes Rendus*, vol. lii., April, 1861; and the supporters of this theory, who go further, and affirm that steel is a union of iron with cyanogen, which can even be seen burning with a violent flame during the process of casting steel. However, up to the present time—1868—the most careful researches of Caron, Marchand, Biot, Bousingault, Rammelsberg, and others, have not confirmed the assertions of Fremy; for, on the one hand, nitrogen is found also in soft wrought iron and in cast iron, and on the other, the quantity of nitrogen found in steel is very variable, and bearing no fixed relation to the quantity of carbon; and furthermore, it exists in such small quantities as to be less than a tenth part of the carbon. For instance, Busengoll found 0·00057 part of nitrogen in cast steel, and 0·00124 part in soft wrought iron.—*Comptes Rendus*, vol. lii., p. 1251. On another occasion, he found in Krupp steel 0·00022 part of nitrogen, and in soft wrought iron and in cast steel, 0·00007 part each.—*Comptes Rendus*, vol. liii., p. 9.

With reference to the influence of different metals on the quality of steel, it is necessary to state that some of them communicate a particular color, some diminish the tendency to rust, and others displacing the carbon, enable the steel to acquire very great hardness in tempering, and so on; but the greater number of substances combined with steel, even in its most insignificant proportions, very considerably lower its quality. For example, the malleability of steel being in direct relation to the quantity of carbon contained in it, is materially lowered by the presence of foreign substances. Bessemer steel No. 1, containing 2 per cent. of carbon, is hardly malleable—Boman, *Das Bessemern in Schweden*, 1864; whereas, according to Anosoff, pure steel retains its malleability with 3 per cent. of carbon, forming the hardest boulat. Speaking generally, all the efforts of metallurgists to obtain the highest qualities of steel should be directed to separating impurities from the raw materials, so that the produce of their operations should be a combination of iron and carbon; and all the specifics and nostrums forming the subjects of so-called secrets will be found to consist, in effect, not in the introduction of new materials, but in purifying the raw, and only, as a last expedient, driving out pernicious impurities by means of substances less harmful. It may as well be said that tungsten steel has not proved a dangerous rival to carbon steel. The fact is that tungsten, when

steel containing it is heated, gradually oxidizes, at first on the surface of the ingots, and then by degrees to the very centre, so that after a few heats the steel loses its peculiar qualities. This oxidation takes place even at ordinary temperatures.

As I have already stated, steel, cast and allowed to cool quietly, assumes a crystalline structure. If you heat such an ingot to a bright red heat, and allow it to cool without working it in any way, then on breaking the mass you will find that its structure has been altered. In order to explain the law regulating the change of structure produced by heating, I draw a line, on which, as on the scale of a thermometer, I shall mark certain points, corresponding to several determined temperatures.



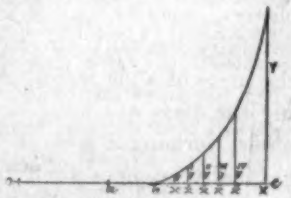
Let the point *o* be the zero of the thermometric scale: *a* marks the temperature of dark cherry-red; *b* red, but not sparkling; and *c* the melting point of a given sample of steel. The points *a*, *b*, and *c* have no permanent place on the scale, but vary with the quality of the steel (in pure steel this variation depends directly on the quantity of carbon contained); the harder the steel the nearer these points move to *o*, and the softer the steel the further off, and, speaking generally, with varying rates. The limits of these movements are sufficiently narrow, so that an inexperienced eye would hardly discern them. Not having suitable apparatus for measuring the temperatures, I have been compelled to denote them by the colors exhibited in heating, the various shades of which only an experienced eye can appreciate; and it must be added, that the colors named have reference only to hard and medium qualities of steel; for in the very soft kinds, nearly approaching to wrought iron, the points *a* and *b* recede very far, so that, for example, in wrought iron the point *b* corresponds to white heat.

The definition of the point *a* is as follows:—Steel, however hard it may be, will not harden if heated to a temperature lower than *a*, however quickly it is cooled; on the contrary, it will get sensibly softer and more easily worked with the file. Not having time to enter into the explanation of this phenomenon, I will refer to the investigation of Jullien (*Les affinités capillaires et les phénomènes de la trempe mis en présence*, Paris, 1866) on tempering in general, from which he deduces the very probable conclusion that steel, in cooling

from a red heat, appropriates a certain amount of latent heat, the quantity of which is directly dependent on the rate of cooling; so that the quicker the steel is cooled the greater quantity of latent heat it will contain; but if the rate of cooling diminishes below a certain limit, then the latent heat all escapes, and no hardening can take place. The actual hardening Jullien explains by the supposition that the carbon assumes an abnormal crystalline condition. I will add from myself that all this takes place only when steel is heated above the point marked *a* on our scale. The definition of the point *b* is that steel, heated to a lower temperature than *b*, does not change its structure, whether cooled quickly or slowly. This expression, however, must be taken conditionally, because steel, during long periods of time, and especially under the influence of shocks or vibrations, and at ordinary temperatures, but to a less extent than wrought iron changes from the finely granular to a coarse crystalline structure; and as regards the heated, and therefore softened, condition, and especially at temperatures approximating to that indicated by the point *b*, it is probable that with the greater facility of motion, the change of structure will take place more rapidly. In my own experiments I have kept pieces of steel at temperatures near to *b* for about eight hours, but after cooling slowly in hot sand, I have been unable to detect any change of structure. As soon as the temperature has reached the point *b*, the substance of steel quickly passes from the granular (or, speaking generally, crystalline) condition to the amorphous (wax-like structure), which it retains up to its melting point, that is, to the point *c*. In this condition steel possesses the property of incompressibility, and, at the same time (with respect to the permanence of the amorphism), has an analogy to an exceedingly concentrated solution of a strongly crystalline salt. To make my meaning clearer, imagine a piece of crystallized alum put into a beaker and carefully heated. On attaining a certain determined temperature the piece of alum will appear as if damp, the separate crystals forming the mass will seem, as it were, to be sticking or clinging to each other, forming a mass on the point of melting, and which actually gradually becomes fluid, and forms a solution of the crystals of alum in their own water of crystallization. Now if this fluid mass is allowed to cool, it will again crystallize, and according to the conditions under which this cooling takes place we can obtain any quality of crystals, from the coarsest to grains so fine as to be scarcely per-

ceptible to the naked eye. If the fluid is allowed to cool very slowly, and in perfect quiet, then large regular-shaped, well-developed crystals will be formed; but if, with the same gradual cooling, the liquid is kept in constant agitation (shaken up), the crystals will come out very small. Allowed to cool quietly but rapidly, the crystals will also be small; and, finally, the least favorable condition for crystallization is when the liquid cools rapidly, and is at the same time violently agitated. In a word, all depends upon the greater or less *time* and the greater or less freedom of motion the particles possess among themselves for collection into crystals; the first condition depends upon the rate of cooling, the second, upon quiet and the greater or less density (thickness) of the mass undergoing crystallization. The same changes take place in the structure of steel heat above the point *b*. The higher steel is heated the softer it becomes, the greater, therefore, is the liberty its particles possess to group themselves into crystals, if the quiet of the mass is not disturbed by extraneous forces; and the slower the temperature is suffered to fall to the point *b* the more time they have for the purpose. At temperatures lower than *b*, as already stated, the structure of the mass does not alter. In this case the action of carbon on iron may be likened to that of water of crystallization on its salt; that is, it may be supposed that carbon at the temperature *b* begins to dissolve iron just like the water of crystallization at certain temperatures commences to dissolve the solid substance of the salt. This hypothesis receives confirmation in the process of cementation, in which the iron must be heated to above a certain temperature or no effect will be produced, no matter how long the bars remain in contact with the carbon; it is very probable that the temperature at which carbon begins to be absorbed in cementation is very near to the point *b*.

The power of steel to become granular may be graphically illustrated thus:—On our scale of temperatures *o*, *a*, *b*, *c*, a curved line rises from the point *b*, and the ordinates *y y*, &c., of this curve represent the degree of development of the grains for the corresponding temperatures *x x x*,



which become the abscissæ, but necessarily under similar conditions of cooling from the several temperatures *x x* to the temperature *b*. At some temperature X lower than the melting point C, the ordinate

Y becomes infinite, and an asymptote to the curve, the practical significance of which is apparent in the well known fact that steel will not endure a high welding heat, but falls to pieces in the fire; and the harder the steel the lower is the temperature at which this takes place, and, therefore, the nearer is the temperature X to *o*, and the further from C.

In manufacturing articles of steel we try to get them as much as possible of a fine grained structure, especially if strength or toughness is the first object sought. I say that it is better to obtain steel of a finely crystalline structure, because numerous experiments have demonstrated that the greater the preponderance of the crystalline formation, the larger and more regular the crystals are in a given piece of steel, the less resistance does it offer to fracture, the less tenacity does it possess, and, therefore, men connected practically with the working of steel recognize its qualities by the appearance of its fracture. If the fracture is fine-grained, they say the steel is well forged and consolidated; if it is coarse-grained, it is badly forged and of an open character.

Although we are in the habit of associating with the forging of steel an idea of increased density, yet, in reality, it appears that, in most cases, forging only changes the form of the steel, and, according to the relations between the force of the blows and the thickness of the piece of steel being worked, hinders crystallization of the mass to a greater or less degree, but does not increase its density—I am speaking only of forging above the temperature *b*, such as is general in working large ingots. The force of the blows is too small to vanquish that gigantic molecular force of heat that keeps the particles of steel at a definite distance one from the other. The problem of forging—at temperatures higher than *b*—consists in this, that while changing the form of the mass of steel, it should have no time to cool and crystallize quietly, but should be kept in the amorphous condition till such time as the temperature sinks below the point *b*, after which, if left to cool in quiet, the mass will no longer crystallize, but will possess great tenacity and homogeneity of structure, so that it will oppose in all its parts a uniform resistance to external forces, of course supposing the chemical composition of the mass throughout to be the same. But if the problem of forging was limited to the above conditions, it is easily seen, that working steel under the hammer might be dispensed with, and the required form given at once by

casting in suitable moulds, and preventing crystallization by rapid cooling. In reality, however, things are very different. The difficulty of forging is aggravated by the circumstance that the cast ingots out of which guns, for example, have to be made, are full of pores, filled with gas, bubbles penetrating the interior as well as the surface of the mass, and also with scales and cracks due to contraction, so that, as the castings are delivered from the foundry, it would be impossible to make use of them. These bubbles and cracks must be squeezed or pressed together, and this can only be done by powerful mechanical means—by heavy forging. Simply unforged cast steel is neither less dense, nor less strong than steel of the same molecular structure, and forged at temperatures higher than *b*. To convince myself of this, I made a number of experiments, first on the density of the two kinds of steel, and found that in most cases forging had diminished the specific gravity; and, secondly, I found, that the tenacity of the cast steel was in nowise less than that of the forged, provided, as I said before, both have the same structure. To prove this, I took a cast ingot of coarse crystalline structure. I had it cut longitudinally into four parts. One of these parts was turned down in the lathe, and tested in the proving machine. The second piece was heated to bright red, and vigorously forged under a 3-ton hammer, the forging being stopped when the temperature fell to very nearly the point *b*; the specimen was then turned down, and also tested in the proving machine. The third piece was made red-hot, very nearly the same temperature at which the forging of the second piece terminated, and was allowed to cool in the open air, without being forged. Having broken a small piece off this last specimen, I found that it had assumed a finely granular structure, very similar to that of the second forged specimen. The third sample was also turned down in the lathe and tested. The three specimens are now before you, and you may judge for yourselves what varieties of structure the self same piece of steel may be made to assume. The results of the experiments are given in the following table.

I must also remark that on the fractured surface of the third sample, as you may observe for yourselves, there is a spot of iron occupying about one-sixth of the area, and which was undoubtedly the cause of premature fracture, for the appearance of the fracture clearly shows that it began at that spot. In order to establish the propositions I have advanced, it will, of course, be necessary to institute a

complete series of experiments.* As regards trials by bending and breaking under the hammer, an immense number of experiments have convinced me of the correctness of my views.

	Ultimate Strength, in tons per sq. inch.	Ultimate extension.	Diameter of specimen—inch.	Dynamic resistance per cubic inch in inch tons. Ultimate Strength × ½ elongation.
1st. Unforged specimen	34·8	0·023	0·885	0·8
2d. Vigorously forged specimen.....	41·5	0·053	0·85	1·1
3d. Not forged, but made finely granular by heating.....	38·7	0·166	0·63	3·21

[To be continued.]

A MODERN ORGAN.*

[From *Nature*, July 27th, 1876.]

It has been hitherto chiefly on the Continent of Europe that connoisseurs in the majestic tones of the king of instruments have had to seek for a grand organ. Though London, the mistress of the world for wealth and magnitude, has churches and chapels innumerable, and organs by hundreds, scarcely one is of sufficient importance or merit to attract the attention of a stranger. Church organs are, as a rule, small, and built without individuality or character of tone, and generally so placed in the building as to effectually mar in acoustical effect any special merit they might otherwise possess. Of the two or three instruments that have any pretensions to magnitude to which the public has access—at the Albert Hall and the Alexandra, and Crystal Palaces, no very lasting impression remains upon the audience beyond that of noise and a distressingly harsh volume of sound, utterly devoid of musical depth and grandeur of tone, and quite different from the pleasing reminiscences that dwell upon the memory from hearing some of their more musical Continental Rivals at Haarlem, Freiburg, or Lucerne. To successfully construct a large organ is a work of exceeding difficulty, for not only does size greatly complicate the mechanical action, but the proper distribution and appor-

* 1875. Since the above was written, numerous experiments at the Abouchoff Works have fully demonstrated the truth of my views.

tionment of the wind to each stop, and the harmonious blending of the whole together in the full organ, demands great knowledge and skill upon the part of the builder. It is for these reasons that very few large organs rise beyond mediocrity, or are noted for the beauty of their tone or the perfection of their mechanism. The great advance in the general taste for organ music within the last few years has necessitated an improvement in the mechanical construction of the organ, so as to enable the performer rapidly to command the entire resources of the instrument at will, and give him absolute control over the various sound-combinations and tone coloring of the different stops, according as they are brought on or off, by means of the appliances placed at his disposal.

We give a brief description of the very remarkable organ recently erected at Primrose Hill Road, Regent's Park, remarkable alike for its size, being larger than the great Haarlem organ, its beauty, richness, and grandeur of tone, and the completeness of its mechanism. At present this superb instrument is almost entirely unknown to the musical section of the public. It possesses what is known as a 32-feet metal speaking front, with a corresponding weight of tone throughout the pedal organ, and its several organs, which together constitute the instrument, give it a conspicuous place in the scale of magnitude as compared with the more celebrated of the continental instruments. The instrument in question has many novelties not to be found in other organs. It possesses seven distinct organs: pedal, great, choir, swell, solo, echo, and carillon organs, each extending the full compass of 5 octaves (61 notes) with the exception of pedal organ, 30 notes. These various organs are under the control of the performer by means of four manual key-boards, which together comprise sixty-seven speaking-registers, and these are combined together with various acoustical effects by means of thirty-one mechanical movements, making a grand total of ninety-eight sound-controlling registers, worked by hand and foot. The entire mechanical action necessary to control these registers and accessory movements is carried out by a novel application of atmospheric vacuum pressure. Two distinct *systems* of main air trunks extend throughout the interior of the organ, in connection with the wind arrangements situated in the basement of the building. One of these *systems* of trunks is for the purpose of conveying the wind at different pressures to the sound boards of the various organs in affecting the musical speech of the several groups of pipes. Thus

the wind supplied to the solo organ, swell reeds, and large pedal reeds, is the heaviest pressure employed in the instrument for producing the musical intonation of the pipes, namely, 6 inches. The wind pressure to the sound-boards of the great organ and swell flue work is 4 inches, that of the choir organ 2 inches, and the pressure of wind is again reduced in connection with the sound-boards of the echo organ to half an inch, the lightest wind upon which any organ has ever yet been attempted to be voiced. This question of wind pressure as affecting the voicing and musical intonation of the pipes of an organ is one of great importance, and upon the skilful adjustment to the size, diameter, and materials of which the pipes are constructed, depends the sweetness and quality of the musical tones produced. In the organ under notice the very light pressure of wind adopted, affords an example for careful study and examination. First, for the mellow sweetness and beauty of tone produced; secondly, for the promptness of speech obtained, as rapid as the articulation of a pianoforte string; and thirdly, for the immense volume of sound and power that can be produced from these light pressures, the combined effect of the full organ rivaling almost the artillery of heaven as thunder, crash after crash bursts upon the ear. Much of the harsh unmusical tone of modern organs arises from this desire to obtain power at the expense of music by the employment of an over-pressure of wind. That age is not requisite to mellow an organ is demonstrated by listening to the diapasons and foundation stops of the Primrose Hill organ, which have all that ripe and fascinating sweetness of tone characteristic of Silbermann's finest instruments. These light pressures of wind constitute a remarkable feature in the construction of so large an organ.

The second series of air trunks which permeate the interior of the instrument are in connection with two large vacuum exhaust bellows which, being continually actuated by the steam-engine used for blowing, maintain a constant vacuum pressure throughout the entire system of trunks, so that at any part of the organ an available mechanical power (that of the pressure of the atmosphere 15 lbs. to the square inch of surface) is at hand to be employed for the multitude of purposes required in a large instrument. To be obliged to have recourse to the old system of wooden rods, trackers, levers, and squares in endless complications, would have so weighted and impeded the action of the organ as greatly to destroy its musical capabilities.

In most of the large organs constructed both at home and abroad, many parts of the mechanism are far from being easy in action and the performer upon the instrument rarely is able to portray with desirable rapidity, his musical creations mechanically at his finger-ends as those creations in tone-color may come to his mind. By the introduction of atmospheric vacuum pressure as the "motor" power, there is no complication of mechanical parts; an almost endless system of tubes being carried from the key-board registers to the sound-board sliders of the several organs. These tubes are in connection with powerful exhaust and vacuum power-bellows attached to the sliders, so that any required stop is brought on or off instantaneously, however distant from the key-board. These tubes may be bent and twisted round corners in any direction, and the parts of the organ most difficult of access easily reached. No mechanical force is therefore necessary to be exerted at the key-boards, the mere touch of a key, register, pedal, or finger-button, at once brings its special tube and exhaust arrangement into operation. The wonderful completeness of this system of vacuum-tube action is beautifully illustrated by means of the echo organ—a complete instrument of 16 feet tone, situated some 100 feet from the key-boards of the great organ—and supported on corbels against an opposite wall at an elevation of some 30 feet from the floor. The action of this echo organ is accomplished by means of electric force combined with the system of vacuum tubes; there is no mechanical communication between the performer at the key-board 100 feet distant and the organ pallets which admit the wind to the pipes, save a small rope of 61 insulated copper wires—one wire for each note of the five octaves. The various stops of the distant organ are likewise controlled without mechanism—a series of vacuum tubes alone extending from the registers at the great organ to the sliders of the echo organ—which are thus brought on or off at the will of the performer by a silent action—at once accurate and instantaneous in its manipulation. The effect of this echo organ, is that of a large organ heard at a great distance. Without the aid of the electric action and vacuum pressure, such an organ could not have been designed. Mechanical action would never have successfully developed such effects at such an extended distance.

The same vacuum system is also applied to the various pneumatic lever arrangements interposed between the keys at the consol and the

wind-valves at the sound-boards to relieve the performer from any undue mechanical pressure that might detract from the promptness of repetition and delicacy of touch of the key action, the key-boards being thus rendered as light as that of a grand pianoforte. Such results cannot be obtained so efficiently by the employment of compressed air for a pneumatic power action; compressed air will always prove to be more or less sluggish, a "creeping on" and "creeping off" movement being the result, besides a limit to the aggregate of the instantaneous power that is at command.

The pneumatic drawstop action of the St. George's Hall organ, Liverpool, is a fair illustration of the defects of the compressed air system. In the Primrose Hill organ upwards of forty registers can be simultaneously drawn on or shut off as easily and with the same precision as though only a single stop were drawn. The consol or key-boards of this organ are reversed, that is, the performer faces the audience, the organ being behind, and the echo organ opposite him. The lowest key-board manual is the "great organ;" the next, or second from the bottom, the "choir organ;" the third in the series the "swell organ;" and the fourth, or upper row of keys, the "solo organ." By a simple mechanical arrangement this fourth key-board is also used for the electric "echo organ," and also for the carillon, or "bell" organ, otherwise it would have been necessary to have introduced a fifth set of keys, an arrangement at all times objectionable from the increased complications imposed upon the performer. The touch of the carillon organ on the fourth row of keys is expressive like that of the pianoforte key, and gradations of tone and distance are therefore capable of being expressed upon the bells.

In this organ the French ventil system of shutting off or bringing on the wind to a complete family or group of stops by the depression of a pedal has not been adopted, such a system being found inadequate to effect rapidly the almost endless combinations that such a large instrument has at command, the pneumatic combination foot pedals and finger buttons at the key-boards being introduced as a more convenient form of manipulating the registers.

The wind supply of this gigantic organ is furnished from four large reservoirs in the basement, which again supply seventeen reservoirs in connection with the various sound-boards of the organ; the vertical feeders for producing the wind to these reservoirs, as well as for creating the vacuum pressure, are set in motion by an eleven horse-

power steam-engine. The wind supply is so ample, that with the power of the full organ it is impossible to exhaust or create unsteadiness in the wind; few organs are properly constructed in this important respect. An ingenious automatic lever engine for regulating the motion and the supply of wind from the vertical feeders into the reservoirs according to the demand of the organ, is placed between the steam-engine and the wind reservoirs, so that the regulation of the wind supply is independent of the speed of the engine, which remains constant. This instrument, which stands 50 feet high, 30 feet broad, and 30 feet deep, occupied three years in construction, and was opened in January, 1876. It has been erected in the large music-room at the Hall, Primrose Hill Road, built expressly to receive it, under the personal supervision of Mr. W. T. Best, of Liverpool, by the eminent organ builders, Messrs. Bryceson Brothers, and Morten, of London, for Nath. J. Holmes.

A VISIT TO THE NEW VICTORIA DOCK WORKS AT EAST HAM.

[From *The Builder*, July 15, 1876.]

The London and St. Katharine's Dock Company are at present engaged in the construction of a very great extension of the Victoria Dock, the intended enlargement of the existing water area of the dock being upwards of 90 acres, in addition to further quay and warehouse space, having a frontage of nearly four miles in length, and covering an area of about 120 acres, the aggregate area of the enlarged dock and quay space being about 200 acres in extent.

The works are now in active progress, and the following particulars, obtained by a visit made last week to the spot, may be interesting.

The site upon which the new dock and quays are being constructed forms a portion of the Plaistow Marshes at East Ham, and stretches in an eastward direction from the boundary of the present dock to the northwest bank of the Thames, where the bank will be entered from the river at a point between North Woolwich and Barking Reach, and about a mile and a half below the first-named place. It is bounded on the north by Beckton and the gas-works, and on the south by North Woolwich. The entire length of the land on which the dock and quays are being formed, from the junction with the existing dock to the river bank, is upwards of two miles, situated partly in the parishes of East and West Ham and Plaistow, in the

county of Essex, and partly in that portion of North Woolwich which forms a part of the county of Kent.

The company obtained an Act of Parliament last year for the works in question, and there has been no delay in their commencement. A large area of land, several acres in extent, at Silvertown, and immediately adjoining the new dock site, presents a perfect village of workshops and huts, which have been erected by Messrs. Lucas & Aird, the contractors, for the purpose of carrying on the works. The excavations for the docks are being actively carried forward, upwards of 2,000 men being at work, and more than a score of locomotive engines, in addition to several excavating machines of American invention, which perform both the work of excavation and also that of conveying the excavated earthwork into the wagons drawn by the locomotives. The amount of excavation to be effected is something enormous, amounting to between 3,000,000 and 4,000,000 cubic yards, of which a large portion has already been executed; the excavated material forming an embankment on the north and south sides of the intended water area, and which will form the site for the quays, and the warehouses, and other buildings to be erected.

In carrying on the excavations some interesting geological discoveries have already been made. From the surface to a depth of several feet the earthwork consists of peat, and amongst it a number of fallen trees, in an admirable state of preservation, have been found. Underneath the peat a bed of gravel has been met with, and below this gravel a stratum of concreted shells and clay have been come upon, intermingled with which stag-antlers and other animal remains have been found.

The water area of the new dock will be 7,640 ft. in length, with a width at the water level of about 540 ft., covering, as already stated, upwards of 90 acres, and it will have a minimum depth of 27 ft. below Trinity high water. In addition to this area the entrance lock from the river into the dock will be 800 ft. long and 80 ft. wide, with strong and powerful gates, which will be opened and closed by hydraulic power.

The entire area of the Victoria Docks and quay space, when the works now in progress are completed, will be upwards of 300 acres, with a circumference of more than five miles.

The enlarged dock, when completed and joined with the present dock, will thus have two entrances, namely, the present entrance on

the west side at Blackwall, and the new entrance now in course of construction at the east end near Barking Reach, there being a river frontage of three miles and a half in length between the east and west entrances respectively.

Near the entrance lock to the enlarged dock below Woolwich, the Ham Hall and Woolwich Manor road intersects the land which will form the lock, and this road is intended to be diverted in the direction of the river, with the construction of a swing-bridge across the lock, to be opened on vessels entering and leaving the dock.

An important feature in the undertaking is the diversion and partial reconstruction of the North Woolwich branch of the Great Eastern Railway. This line runs immediately along the northeast side of the present Victoria Docks, intersecting a portion of the site upon which the enlarged dock is in course of construction, and in order to admit of the extended dock being connected with the existing dock, the North Woolwich line is to be diverted, and carried under the dock by a tunnel at a depth of 43 ft. below high-water mark.

The facing of the dock walls will be of granite, several feet in thickness, and in addition to the large quantity of stone which will be required, it is estimated that not less than 30,000 tons of Portland cement will be used in the construction of the works.

It is calculated that the new works, the estimated cost of which is nearly 1,000,000*l.*, will take about three years to complete. They have been designed by Mr. A. M. Rendel, C. E., of Great George street, Westminster, Mr. Anross being the resident engineer.

The magnitude of these works suggests a comparison between the area and extent of the London docks, and those on the banks of the Mersey, at Liverpool and Birkenhead. The estimated water area and quay space of the London and St. Katharine Docks are about 120 acres; the East India Import and Export Docks, 32 acres; West India Import and Export Docks, 54 acres; South Dock, 24 acres; Timber Dock, 21 acres; Commercial Docks, 150 acres; Grand Surrey Docks, 75 acres; and Victoria Dock, 90 acres (exclusive of enlargement in progress; being a total of 566 acres. The water area and quay space of the Liverpool docks are 259 acres, and that of the Birkenhead docks 166 acres, being a total of 425 acres on both sides of the Mersey, as compared with 566 acres, the present area of the docks on the Thames, exclusive of the Victoria dock extension now in progress.

GAS WORKS ENGINEERING.

By Robert Briggs, C. E.

[Continued from Vol. cii, page 104.]

"An exhauster is a pump, generally rotary, which is used to pump the gas against all pressure to which it may be subject between the hydraulic main and the holders. To state these pressures in reverse order, they are—first, those of the holder, which, with telescopic holders, is variable, and amounts to from three to five and a half inches of water column; second, those of the purifiers, varying but little from two and a half to three and a half inches for lime purifiers (with lime of usual quality and condition); third, those of the washer, condenser, pipes about the works, &c., grouped together, of perhaps one to one and a half inches; giving a total of six and a half, to ten and a half inches of water-pressure. Now it has been found that any increase of pressure on the retorts over the half-inch of seal for the main, occasions a peculiar destructive distillation (probably of the first formed hydro-carbons, and possibly those formed before the coal is well heated), whereby solid carbon deposits by accretion upon the inside of the retort, especially at the back end, and rapidly fills it up and impairs its heat-conducting and gas-forming powers; and hence it is requisite to suck the gas from the direction of the retort, and force it in the direction of the holder, until the retort is relieved from everything but the hydraulic seal pressure.

"As these total pressures vary in amount from time to time, and from hour to hour, and as the quantity to be pumped varies in the same way; the exhausters are driven by separate engines, regulated for the procurement of the pressure desired on the hydraulic main, and are always provided with steam-power enough to overcome the largest resistance, and to impel at the same time, the largest quantity of gas presenting itself to be moved. Experience has suggested, and ingenuity provides, all the safeguards for successful automatic accomplishment of the requirements here stated, and the exhauster has become one of the most reliable parts of a gas apparatus. The necessity of my allusion to this portion of the working machinery in its place of application in the Market street works will appear when noting the question of purification.

"There are, at the Market street works, three '*sets*' of purifying '*boxes*.' A set of purifiers is four in number, three of which only

are in regular use at any one time. The thirty-six inch main-pipe is brought into the purifying-house, where three branches of twenty or twenty-four inches diameter are taken from it, which branches are joined to, and form the main inlet-pipe of the '*centre-valve*' of each set; while, from the centre-valve, three main '*outlet pipes*' lead away, and convey off the *purified* gas, to another thirty-six inch main-pipe; and this last and final pipe of the gas-works goes to the great meters, and thence to the holders where the gas is stored.

"The centre-valve needs a brief description to be understood. It is a large cast-iron box, with numerous internal divisions, and it is three stories in height; to the bottom story, the main inlet and outlet pipes are joined; to the next story or '*body*,' four *pairs* of pipes connect, one pair going to each of the purifiers; while the upper story is a circular '*cover*,' which is loose, and can be turned on its axis.

"The cover fits gas-tight on the body, and has internal divisions corresponding (but not agreeing) to those of the body. The arrangement of the divisions is such, that if the cover be placed in a given marked position, the gas will now enter the main inlet-pipe, pass through one of a pair of purifier pipes and return again by its mate pipe to the centre-valve; then pass out of the centre-valve through one of the pair of next or second purifier pipes and return by *its* mate; and so to another or third purifier, and back again to the centre-valve; but now, in place of going to the fourth purifier, the gas will pass out of the centre-valve by the outlet main; thus the fourth purifier will have been shut off altogether. This same course of events will follow when the cover is turned a quarter of an entire rotation; only that the purifier before shut off will have become number one of the series, and the purifier before number one will have been shut off. The operation of the centre-valve may be otherwise described. Suppose a set of four purifiers are designated by the letters A, B, C, D. Now, the different positions of the centre-valve may be assumed to be as follows:

	First.	Second.	Third.	Out of use, shut off to be cleaned.
First position of centre-valve (cover),	A	B	C	D
Second position of centre-valve cover (¼ turned), ...	B	C	D	A
Third position of centre-valve cover (¾ turned), ...	C	D	A	B
Fourth position of centre-valve cover (¾ turned), ...	D	A	B	C

"The next one-quarter turn of the cover will obviously restore *everything* to the first position; and, by this exposition it will be made evident that the gas, when passing through the three purifiers in operation, will have entered the one longest in use and escaped from the one most recently cleaned. Purifiers are made (for dry-lime purification) of the proper size, and with the proper dimension of pipe connection and centre-valve, to demand the cleaning of one of them each twenty-four hours.

"The purifiers at the Market street works are of the customary construction, that is, cast-iron '*boxes*' with wrought-iron '*covers*;' the covers having 'sides' (a rim projecting downwards) which drop into a '*cup*' or trough, partly filled with water, which cup surrounds the sides of the boxes; the '*seal*' thus made forms the gas-tight joint between the covers and the boxes.

"In this instance, the dimensions of any one of the purifiers are twenty-four feet square on the floor by three feet three inches deep, inside measurement. Inside of the boxes is placed seven layers or flats of perforated iron or wood movable '*screens*,' and upon these screens is spread damp slaked time in layers of two and one-half to three inches in thickness. [This damp slaked lime is called 'dry lime,' in contradistinction to thick liquid lime-water, which is called 'wet lime.'] The gas enters at the bottom of the first purifier-box, ascends, percolating through the seven layers, to the top; a pipe which passes down through the screens to the bottom, carries off the gas (through the centre-valve) to the second purifier; where the same operation follows; to the third with like result; and from the last it passes out, purified, ready for distribution to consumers.

"The lime used at the Market street works is oyster-shell lime; and, from the annual report of the Trust, I gather that there is used for every five thousand cubic feet of gas made very nearly one bushel of lime; and as the same authority shows (by estimate) the production of about 4·4 cubic feet of gas from each pound of coal, it follows from the six charges of two hundred pounds to a retort, that there are needed a little more (1·06) than a bushel of lime for each retort in service; and furthermore, as the works are planned for three hundred retorts for each set of purifiers, that three hundred and twenty bushels of lime will have been vitiated in the working of any one set; and finally, that nine hundred and sixty bushels of lime will be the maximum daily demand.

"The manipulation about the purifiers is as follows: A quantity of lime is slaked (in an adjoining shed) by the addition of about an equal weight of water; a little over one-third its weight of water is taken up chemically, and forms the dry hydrate of lime (which is in fact the binding material of ordinary lime-mortar), a portion of the water is evaporated, and the remainder or excess of water gives the requisite dampness for the process of purification. Unless compacted by stirring or beating, the slaked lime has about twice the volume of the quick-lime and about twice the weight, and in this condition (for it is desirable that the mass should be as porous as possible) it is removed to the purifying house to be spread upon the trays as described.

"After a purifier is charged and put in its place at work, the foreman of the purifying-house will test the gas in it from time to time. The test is performed by the exposure of two strips of paper to a small stream of gas, which is allowed to escape by a cock on the covers of the last purifier put in use.

"These papers have been prepared, one for a sulphur test of blotting-paper wet with acetate (sugar) of lead, which blackens quickly if any sulphur be present; and the other, impregnated with litmus or turmeric solution; litmus becoming blue, and turmeric red, if any ammonia exists in the gas.

"So soon as the sulphur-test shows the presence of sulphur in the last box, it is time to change and bring into action, as first and second purifiers, those which will take their place in due sequence, and which have not been so much '*fouled*' as to cease to act properly; and it results from this changing, by *test*, that there will *not* be a change of purifier each day, but only, whenever necessary; the construction of the apparatus, however, having been planned for proper distribution of labor, to give a daily change to a set, when in regular work.

"The test having given the legitimate indication, the last purifier of a set is thrown out to be cleaned; and the centre-valve being shifted, a large nozzle (which is to be found on each cover) is opened to release the gas enclosed in the box, when the cover is lifted by a traveling apparatus for the purpose ('*carriage*') and transported away (over the boxes in use); and after an interval of time for the dissipation of the enclosed gas, the workmen commence the removal of the '*foul-lime.*'

"This foul-lime is taken in wheel-barrows and removed into the open air. The place of dumping is forty feet from the purifying-house, in an open yard on the bank of the Schuylkill, about forty feet from the edge of the wharf along the river, and about one hundred and fifty feet distant from Chestnut street Bridge. The level of the wharf is about thirty feet below the roadway of the bridge, and the level of the purifier-house floor about six feet above that of the wharf. A low wall, forming an angle, supports the bank at the dumping place, and the foul-lime is deposited in a heap from the top of this wall.

"At the time of my first visit to the gas-works, in February, 1876, there was a barge receiving the spent-lime from carts, which were hauling it across the short space of the width of the wharf; on the occasion of a subsequent visit in March, 1876, there was none going away, but a number of laborers were breaking up frozen foul-lime from the bottom of the dump where it had collected. I was told that, generally, there were barges ready to receive the material, but not always, and that sometimes the foul-lime was hauled away in carts and wagons;—whenever a farmer came for it, it was given to him.

"To a visitor of a gas-works, where the delicate sense of smell is quickly impaired, the foul-lime in the purifiers is not exceedingly offensive, and at the moment of discharging one of the boxes and of the dumping of the material in the heap, the offensiveness is not so decidedly evident; but after short exposure to the air, and especially to damp air, or when, having become wet, it is permitted to dry in the sun, the propagation and dispersion of effluvia is disgusting, even to those employed in the works, and whose business it is to endure the smell. A somewhat active decomposition of some of the constituents of the foul-lime certainly occurs after exposure to the air, as is evidenced by an increase of heat, and it is certain that this decomposition does not destroy the odoriferous substances.

"In the analysis and purification of gas, by the Rev. W. R. Bowditch (one of the most practical scientific writers on the subject), 1867, will be found (folio 19, *et. seq.*) these words:—

"'About this date (1844) the use of gas was increasing very rapidly, and gas companies in London and some large towns were sadly encumbered with, and troubled about, the lime refuse which arose from purifying their gas. Purified the gas must be. Sanitary regulations most properly prohibited the running of Blue Billy (the

foul liquor of the original wet-lime purification process) into streams and rivers, and even, in some cases, prohibited the carting away from gas-works of dry-lime refuse during the day-time. Matters seemed to be approaching a crisis, when, in 1849, Mr. Hills came to the rescue, and introduced sesquioxide of iron as a purifying agent instead of lime.'

(To be continued.)

TIMBER NOMENCLATURE.

[From the *Timber Trades' Journal.*]

It is impossible to take up any feature or subject so closely associated with the common wants of man as that of timber, without finding in its name something of absorbing interest. As a material it ranks second to no other, either in connection with man in his rude and primitive state or under the high polish of civilization; so closely is it associated with his everyday life that we may say of it as of his shadow—it is always with him. A mere glance at the vocabulary pertaining to timber shows that it abounds in monosyllables, and that words of a compound character are the exceptions. This fact points with unerring truth to the rude and simple language of our Saxon ancestors as the source from which it is drawn. We find, so far as this country is concerned, that the Celtic and the Roman "tongues in trees" have failed to reach our times, and that names of a Norman origin occupy no prouder position than parasites upon the grand old Teutonic stock. The study of this subject carries us back to an early period in the Christian era, when our eastern coast was called the "Saxon shore," when every creek and river mouth of this fertile spot "set in the silver sea" was infested with the blue-eyed strangers of the north; it shadows forth a time when like a wave this intruding race swept over the land, blotting out in its devastating course the vernacular of its predecessors, and setting up a standard tongue which, with sundry changes consequent upon the wearing effects of time, has endured to the present day.

Ash, in alphabetical order, claims our first attention. It is the "aesc" of the Anglo-Saxons, and the "ast" and "ask" of the Swede and Danish dialects. From being the wood of which the lances, spears, and shields of our forefathers were made, it became

par excellence the tree of war, and, unlike its present feminine, the "queen of the woods," was endowed with masculine attributes. It held the high distinction of being the personification of strength and valor, and it was a tenet of the heathen faith of the northern nations that the first man Æsc was made from the wood of this tree. From this belief it became a personal name of the highest honor, to be worn only by those of royal blood. Æsc, the son of Hengist, is an instance of its application in historic times, in which case it implied that his genealogy was traceable to this ancient source. It is noteworthy that the Greeks and Romans made their spears or pikes of this wood, a custom also obtaining with the Saxons, who called this warlike instrument an "aesc."

Balk, or "baulk" as applied to a log of wood, is from the Saxon *balc*, the German *balken*, and the Dutch *balk*. In the former dialect, it had a more extended meaning than it bears at present, as we find it implied a beam, a roof, a covering, or a balcony.

Batten is from the Saxon "bat," a boat or ship, and implies a piece of wood suitable for making or building such vessels. The club or bat of the cricketers, as applied to a piece of wood, is allied to this word.

Beam, from the German "baum," a tree—in the sense of a tree, the word still lingers with us in horn-beam—horn-tree, its primitive meaning was a rough-hewn tree used for constructive purposes.

Board is the Anglo-Saxon "bord," and German "brade," a thin plank. This word has been highly wrought upon, from being made of boards, we find it applied to the deck of a ship, also to a table, and hence those that assemble round it, and even the food placed upon it.

Charcoal is a compound of the Russian and Anglo-Saxon tongues; "char" is to burn or reduce to coal or carbon, and "coal" is a term referable to a black substance. Charcoal means literally wood reduced to impure carbon by expelling the volatile matter. In the early history of the iron trade of this country, it was an ingredient of the first importance; our present name for fossil coal is borrowed from this material. When made from beech-wood, it was called "beech-coal." Charcoal burners were called colliers, an occupation or calling which furnished the family names of Collier, Collyer, and Colyear.

Chestnut, sometimes called Spanish—from the fact of the best fruit coming from that country—is from the Anglo-Saxon "cyst-beam," literally the fruitful tree; being a tree requiring a warmer climate to ripen its fruit than that prevailing in this country, it is naturally inferred that it was a tree little known to our rude ancestors. Be this as it may, the fact remains that they were present at its christening. The horse-chestnut was so called upon its introduction from Asia in 1629, the term being a mere translation of its classic name, *hippocastanum*.

Deal is the Anglo-Saxon "dael," and the German "diele," a part or portion, hence a piece of wood. In early times it most probably referred to a riven piece, as a riving axe was called a "deal axe;" we still retain the word in "a deal of cards," meaning a division or portion of the whole. So far as the timber trade is concerned, the term "deal" appears to have been applied alike to the fir and the spruce, the "mast-tree" and "deal-tree" being common terms long before it was known what trees they were the products of.

Elm, from the Anglo-Saxon "elm," "ellm," or "ulme," and the Dutch "olm." This name occurs, with slight variations, in all the Celtic dialects. From the fact that the elm rarely ripens its fruit in this country, coupled with the resemblance of its name to the classic *ulmus*, it is looked upon as a doubtful native. The term "wych elm" is supposed to refer to its ancient use for water pipes, especially in connection with salt-springs, erroneously supposed to have been called "wycs" and "wics," as in Nantwich, etc. The writer is of opinion that the term "wych," also referable to the hazel, and the mountain ash, is merely a varied form of "withe," a lithe or pliant rod or twig.

Fir, as a term, embraces all the best known coniferous trees, such as the Scotch fir, the spruce fir, and the silver fir; it applies to trees of a resinous character, easily ignitible, and consequently suitable for fuel, for torches, and firebrands. Gerard says, "the fir-tree" was originally the "fire-tree," an inference that all investigations confirm, and there can be no doubt upon comparing the Anglo-Saxon "fyr," fire, with the Scandinavian "fyrre," fir, that the terms "fire-wood" and "fir-wood" are synonymous.

Forest is an Italian or Armenian word which has reached us through our French or Norman connections; it appears in the German language as "forst." Our ancient forests were called "woods,"

as in Sherwood; but the intruding term, although superfluous, has tacked itself on behind, hence the common phrase "Sherwood forest." The Saxon "woodward," from this change of dialect, became the Norman "forester;" as an occupation it was of sufficient importance to found a large family of personal names, hence those of Forrester, Forster, and Foster.

Log is an old Dutch term for "heavy," hence a heavy piece of timber is so called. The equivalent in the German tongue is "klog." In America, where the mother tongue is subject to great mutations, the act of rafting timber has got corrupted to "logging."

Lumber, dry, household rubbish, has taken the place of the term "wood" on the American continent. With the early settlers, whose all lay in the cultivation of cereals, timber was an incumbrance to the land; and although it has long since raised itself into a marketable commodity, it has failed to free itself from this term of ridicule.

Oak, the Anglo-Saxon "a'c," "aec," and "aac," and German "Eich." The first form is preserved to us in the fruit "a'ccorn," the corn of the oak. In ancient times it was a tree prized for its fruit, being used for fattening swine, and, in time of dearth, as human food. Oak woods were estimated by a number of hogs they would fatten, proof of which we find in the Doomsday Survey, where woods of a single hog are enumerated. Pliny says, in his time acorns formed the chief wealth of many nations. The etymology of this word is difficult to arrive at; it appears to be a term peculiar to the north of Europe. We find it in "ac-drenc," oak-drink, a drink made from acorns, and "ac-wern," a squirrel. This interesting animal was known by this ancient name before we borrowed the present one from our French neighbors.

Plank runs through the French, Dutch, German, and Danish languages with little variation. It implies a flich of wood, thicker than a board. It is a term which no doubt reached us through our early trading connections with the Low Countries.

Poplar, like all other trees, whose names rise above simple monosyllables, is supposed to be introduced. The white and the aspen poplars are the trees with which our forefathers were familiar; the black and the Lombardy varieties being recent introductions. It is generally thought that this tree was introduced as early as Roman times, an opinion which derives support from the resemblance of the name to the Latin *papulus*. It is supposed by some writers to have obtained this classic name from its being the tree selected for the

decorations of Rome, *arbor populi*, by others from its leaves being as easily agitated as the minds of the people. It is curious that Sir Walter Scott uses this simile :—

> "Oh, woman, in our hours of ease,
> Uncertain, coy, and hard to please;
> And variable as the shade,
> By the light quivering aspen made."

Spruce occurs as Spruce fir and Norway spruce. The former is the older or original term, and if rightly read is simply descriptive. Spruce fir is the old Prusse, or Prussian-fir. It occurs in the manuscript of *Liber Albus* (*circa* 1250), as "pruz-fir." It would appear that there was little or no distinction in these early times between Prussia and Russia, as the Russian leather of our day was the Spruce leather of the Dutch merchants, who, during the Hanseatic League, had their seat of trade at Wisby, in the Baltic. It was through their instrumentality that the produce of the Baltic shores reached England *via* Amsterdam, and from this cause may be traced the numerous lowland terms that abound in our nomenclature of timber. It will be seen that as the timber trade moved to Norway, the term spruce accompanied it, and hence "Norway spruce fir" has long been held as the equivalent of "white deal." The same remark applies to America, where "spruce" stands for the "white fir" of that continent. In unearthing the meaning of these ancient terms, the first form in which they were used contrasts strangely with their present use. In the case in point, we should scarcely be credited with the exercise of sound reason were we to write "American Prussian fir" for "American spruce fir," although such term would be orthographically correct.

Stave, from the Anglo-Saxon "stæf," a staff, stick, or pole. It occurs in "flag-staff," "ladder-stave," and cask or pipe-stave," and implies a light round pole, or a hewn or riven piece of wood, smaller in character than a deal. In mediæval times the term stave was largely used in connection with bows. It is certain that bow staves were of ash, elm, and yew, but the term stave is now wholly associated with the oak, and there can be little doubt that staves for the cask trade have been made of this wood from the earliest times. It is a point worthy of investigation whether the wainscots of the fourteenth century were not riven staves for the cooper; certain it is that their value was only one-fifth that of bow-staves.

(To be continued.)

Chemistry, Physics, Technology, etc.

PETROZCENE AND ITS PRODUCTS.

By Dr. Herbert W. C. Tweddle.

Petrozcene is a hydro-carbon and a product of the dry distillation of the residuum, or tar, from petroleum. It sublimes over at the latter end of the distillation, accompanying a thick resinous oil of about ·980 specific gravity.

In its crude state this mixture of oil and petrozcene is bright orange in color, which rapidly becomes dark green on the surface by oxidation; hitherto this substance has been almost valueless. From it petrozcene is separated by lixivation with benzine and when thoroughly separated from the oil, it is obtained as a yellowish green crystalline, extremely light precipitate.

If only the early product of the last portion of the distillation is lixiviated, the precipitate obtained is a canary yellow and is called "Thallene," this substance was examined by Prof. Henry Morton, to whom I sent some for examination, (*vide* Journal of Franklin Institute, Vol. LXIII, Third Series, page 296, and Vol. LXIV, Third Series, page 273, A. D. 1872).

Petrozcene fuses at 420° to 425° Fahr. Its specific gravity is 1·2066. It is crystalline and dark olive green in color, not very hard, but brittle. After fusion, if heated to 500°, it sublimes, giving copious yellow vapors, which, if it is desired to collect, require a large condensing surface. If heated in a close vessel to about 600° it distills over rapidly, (the still must have a large fire surface, a very short condenser kept at least 300° to 400°, and made to drop with steep incline) and deposits in the still a large amount of separated carbon. It is inflammable and burns an extremely sooty red flame, emitting a slight pungent empyreumatic odor.

After fusion, if poured out, it chills rapidly, but retains heat VERY tenaciously. In cooling it shrinks very much, cracks and sometimes falls to pieces, its surface is crumpled, somewhat iridescent and metallic in appearance, its fracture in large masses exhibits a highly crystalline structure.

The crystals are thin uranium green colored plates, transparent, and of a foliated structure, resembling some varieties of graphite. When petrozcene is kept fused at a high temperature for some hours it is partially decomposed, and when cooled in masses of one or two hundred pounds, separated carbon is found permeating the entire interior structure, in this state the crystals are very beautiful, resembling spiegeleisen, though not so large.

When petrozcene is distilled in large quantities, and proper care exercised, it can be separated into a series of interesting and beautiful products, in fact I know nothing distillable (if I may use the word), among organic or inorganic bodies, that affords such beautiful kaleidoscopic effects from the beginning to the end of the operation. The products I classify as follows:—

The first product is water, accompanied and followed by a yellow-green sublimate which I collect and call "petrozolene," it fuses at 373° to a light green crystalline body. This gives off a white vapor with an empyreumatic odor, a little above its melting point; accompanying this sublimate is a distillate which chills rapidly with a brilliant green surface; it is semi-transparent and much more crystalline than petrozcene, in large masses it is very beautiful, this substance I call "carbozcene," it fuses at 398°, and commences to volatilize at 470° Fahr., giving copious yellow vapors.

This distillate is succeeded by another, requiring a higher temperature to distill, it is brownish green in color, crystalline, and fuses at 422°, volatilizing at 550° Fahr., this substance I call "Bi-carbozcene."

At this point the green sublimate, petrozolene, disappears and is succeeded by a golden orange sublimate which continues to the end of the distillation, this I call "Bi-petrozolene," it fuses at 442° Fahr. to a dark brown crystalline body.

The third portion of the distillate is bronze yellow in color, crystalline, fusing at 452° Fahr. and volatilizing at 480° Fahr., this I call "Tri-carbozcene."

The fourth portion of the distillate is dark orange in color, accompanied by copious vapors of Bi-petrozolene; it is crystalline and fuses at 460°, its volatilizing point is above 550°, this body I call "Per-carbozcene."

The fifth and last portion of the distillate changes rapidly in color to a dark bronze green, almost black; it is crystalline, and shrinks and cracks to pieces on cooling, this I call "Carbo-carbozcene," its fusing point I did not get.

The residue in the still is a heavy intumesced mass of carbon, (which I will analyze, and send result at some future time).

All the sublimates when in powder lose in a few days their brilliant colors by exposure to light, assuming superficially a buff tone.

Petrozcene is readily oxidized by boiling with Bi-chromate of potassa and nitric acid, producing a red compound, nitro-petrozcene, which is susceptible by chemical treatment of producing fast dyes and colors. Petrozcene is carbonized by sulphuric acid, it is insoluble in water and glycerine, partially soluble in alcohol, benzine and turpentine. It resists the action of caustic potash, soda or organic acids. It is odorless, and rubbed between the fingers, it is at first yellow, then green, and has a resinous feeling. It is not a conductor of electricity.

It and its products are highly fluorescent (the green fluorescence of petroleum, paraffine oils of commerce is due to it). Whether petrozene will become commercially valuable the future will determine; but to the scientific world it will no doubt be a study of great interest, not only for its novelty but for its close analogy to some of the metal group, and its peculiar fluorescent properties (see Prof. Morton studies, before referred to, on "Thallene").

Between petrozcene and its products and sulphur there is a marked analogy, as far as physical characteristics are concerned, but no further. In manufacturing it, it irritates the skin somewhat, and it has this peculiar effect, that if you work with it too much, either by itself or among its subliming vapors, you get some green in your eye, *id est*, your vision sees objects green instead of their proper color. This, however, passes away after some hours. It is not poisonous when taken internally in small quantities.

Petrozcene can only be produced in limited quantities: 50,000 barrels = 2,100,000 gallons of Pa. petroleum, of 48° Beaumé, spec. grav. yielded only four hundred pounds of petrozcene precipitate, although this might probably be increased by proper treatment in the earlier stages of manufacture.

The resinous oil which accompanies the petrozcene is recovered from the benzine washings by distillation, and produces a valuable paint oil and varnish, which oxidizes rapidly and dries hard.

Very small portions of the sublimates can be procured, but of the crude petrozcene and its distillates, I have obtained so much as to be able to give, in moderate quantities, to scientific men for experimental purposes.

TABLE OF PETROZCENE AND ITS PRODUCTS.

Petrozcene fuses at . . . 426° Fahr. " specific gravity 1·2066	Color is dark greenish-yellow, becomes dark olive green and crystalline by fusion.
Thallene fuses at . . . . 406° "	Color light canary yellow, fuses to a dark green crystalline body; volatilizes a little above its fusing point.
Petrozolene fuses at . . . 373° "	Is a green sublimate from petrozcene; it fuses to a light green crystalline body.
Bi-Petrozolene fuses at . . 422° "	Is a golden orange sublimate from petrozcene; fuses to a dark green crystalline body.
Carbozcene fuses at . . . 398° " " volatilizes at . 470° "	Is a light green crystalline distillate from petrozcene.
Bi-Carbozcene fuses at . . 422° " " volatilizes at 550° "	Is a brown green crystalline distillate from petrozcene.
Tri-Carbozcene fuses at . . 452° " " volatilizes at 490° "	Is a bronze yellow distillate from petrozcene.
Per-Carbozcene fuses at . . 460° " " volatilizing point too high to obtain with mercury thermo.	Is an orange colored crystalline distillate of petrozcene.
Carbo-Petrozcene, fusing point unknown.	Is a dark bronze green crystalline distillate of petrozcene.
Nitro-Petrozcene, bright red compound.	
Petroleum Mastic, specific gravity 3° Bauum Hydrometer.	This oxidizes rapidly like boiled linseed oil, and will make good varnish, and is the only product of Pennsylvania petroleum that I know of that will oxidize in this manner.

It is somewhat to be regretted that the names for these apparently new hydro-carbons, have been assumed by the writer of this article before analysis had designated their place in the scale, and established the appropriateness of denomination. It is however proper that a priority of discovery should be asserted at this time by Doct. Tweddle. —Ed. F. I. J.

USE OF SODIUM SULPHIDE IN TANNING.*

By W. Eitner.

[From the *Journal of the Chemical Society*, June, 1876.]

Tanners have long since perceived that lime does not in all respects afford the means of preparing the skins for a thorough tanning. After some speculations, they have succeeded in improving the lixiviating process.

The favorable action of soda when added to the lime having been noticed, three depilatories were used, viz., the long-known "rusina" Böttger's green lime and gas green lime, each having hydrosulphide of calcium as acting substance. These agents were applied to the hair side of skins, and in a few hours dissolved the hairs in proportion to the quantity of sulphide they contained. The hair was of course rendered perfectly useless, but by macerating the flesh side with lime, it was not destroyed; moreover, the skins did not lose any valuable substances.

Lindner (1855; 137·221) prepared an aqueous extract of the above agents, by which a large portion of impurities was removed, and dipped the skins in this clear solution, the strength of which can be regulated by a Baumé's hydrometer. The skins were thus cleansed much better and more quickly, and experienced tanners, like Kampfmeier of Berlin, considered the leathers produced by this method superior to limed leathers.

Sulphide of lime, however, in its above-mentioned forms has several disadvantages. In the form of rusina it was commercially too expensive, and containing poison could not be recommended. Böttger's green lime also is too dear, and the smell of sulphuretted hydrogen it causes in works is disagreeable; gas-lime, however, is at present very

* *Dingl. Polyt. J.*, ccxviii, 355—361, 437—453, and 508—517.

scarce. It was therefore necessary to obtain alkaline sulphides cheaper than sulphide of lime.

M. Louis Matern, of Antwerp, exhibited at Vienna in 1872 a new depilatory liquor, and an apparatus constructed by him, by which skins treated with his liquor were depilated.

The author analyzed this liquor, and found it to contain slaked lime, soda and sulphur approximately mixed, but as the specially acting substance he discovered sodium sulphide. M. Matern evidently thought that the total mixture and not one special substance produced the desired effect, and used it merely for depilating sheep and goat skins.

Eitner in 1873 treated skins of calves, bullocks, and horses with this liquor very successfully, finding from the commencement of his experiments that the mixture was the more effective the more sodium sulphide it contained, and he therefore resolved upon using this substance exclusively. He obtained perfectly pure sodium sulphide from de Haën, and the results of the depilation were very remarkable. Bullocks' skins were depilated in 15 hours, and calf skins in 4 hours. De Haën at once understood the importance to be attached to this re-agent, and therefore began to prepare it on a large scale.

The author next describes the uses of sodium sulphide as special depilatory in the manufacture of under-leather, in the first place strictly in regard to sole-leather, and secondly with regard to thin leather, as used for the inner soles of boots.

In the case of the sole-leather, loosening of hair is the only object in view, and this is effected either by the different sweating processes, or by placing the skins in fermenting barley-groats, &c. The skin is said to be only slightly altered in its outer parts, the real leather and other parts retaining their natural condition. This latter fact, however, is ensured much better and more safely by using sodium sulphide, and in this case this method will be seen to be in conformity with that of sweated skins, whereas with other kinds of leather, the tannin has to be modified. The following constitutes the depilatory operation:

The skins are spread out flat upon each other on their flesh side, and then painted with sodium sulphide, care being taken to brush the solution over the hair in such a manner that it touches the skin. After this is done the skins are folded together, put in a warm place

not below 19°, and covered with a wet rug, to prevent them from drying. In about 15 hours the skins are ready for depilation.

The solution is prepared by dissolving a weighed quantity of crystallized sulphide of sodium in hot water, using 1 kilo. of the salt and 2 litres of water. This solution must be thickened with lime, using 3 parts to 1 of sodium sulphide. The quantity of sodium sulphide required in depilating the skin of a bullock varies, according to the size of skin and quantity of hair, between 100 and 120 grams. Dried skins require 17—35 grams more salt.

It is necessary to apply the solution to all parts of the skin, more especially to the head and along the back, and to remove any stones or coarse sand from the lime, which prevents the solution from acting. It is also a matter of course that the skins should be soft before treatment, and if dirty on the hair-side, they should be well cleaned.

Before removing the hair it is advisable to wash the skins in water in order to get rid of the caustic depilatory, otherwise the hands of workmen would suffer very severely. The washings need not be saved.

After removing the hair, the skins are placed in fresh and hard water, partly to wash them, but partly also to swell them, because without this the fleshing of the skins would be rendered very difficult and perhaps impossible. The leather clippings obtained from the fleshing are identical to those of sweated skins, and must be treated with lime before boiling them up for glue. After the fleshing, the skins are treated in the usual manner, and tanned like sweated skins.

With regard to the manufacture of the second class of under leather, viz., leather used for inner soles of boots, the results were not so favorable with sodium sulphide.

The main part of the tanning of such leathers is not entirely effected in the pit, where the acids are formed, and which, next to tannin, are the most important agents in the preparation of under leather; but a preparatory tanning already takes place in the ooze, which latter represents the principal feature in the manufacture of upper-leather. The difference between this under-leather and sole-leather is sufficiently marked by the edge and the felting of the fibre.

In tanning sole-leathers, the outside of the skin is only colored in the ooze, and the at first dead and shriveled fibre is swelled by the

acids, and in this state, by the action of acid and tannin on the natural fibre, it is converted in the pit into leather.

Inner sole-leathers which were formerly treated with lime, and although they lost part of their grain, were nevertheless brought into the ooze in the swelled state, do not at first require acids for the swelling, but so much the more tannin to prevent them from being spoiled. This tannin enters into the leather with comparative quickness, because it is absorbed much better in the ooze than in the pit, and because the lime, which dissolves and removes many portions of the skin, thus leads the way into the inside of the skin. These leathers therefore contain more tannin and less acid than sole-leathers.

Skins depilated with sodium sulphide, as already mentioned, completely resemble those of sweated skins, but differ from limed skins; the former therefore in their first period of tanning require another treatment.

Under all circumstances skins depilated with sodium sulphide are less swelled than limed skins, and become less swelled in solutions in which limed skins become well swelled, because the former have obtained a preliminary swelling through the lime, whereas the latter are still in their natural condition. The oozes in which these skins are to be tanned must therefore contain more acid than lime-oozes. From the degree of tanning and swelling of the skin tanners are able to determine whether skins are ready for their second treatment. The reason why the tanning is slower and a larger quantity of tan has to be used is the following: In the first place these skins contain more material to be tanned, for nothing has been taken out; and secondly, their texture is for this very reason firm and close, whereas lime loosens and partly destroys it.

The addition in the quantity of tannin can take place at either of the following two stages. We can either give the ooze more material in the first tanning, by adding more tan or using one or two more tans, and thus obtain a leather of greater firmness and suitable weight; or we can use the ordinary number of tans, but allow every separate set to stand for some time after having added more tan. In this case we form a leather which is more like ordinary sole-leather.

Tanners who work with galls, valonia, and myrobalans can use the first method, but to those working with tan the latter method may be recommended.

The last-described process can be used only when the hair side of skins has been treated with sodium sulphide. Hair, however, is often too valuable to be totally destroyed, which of course would be the case in the above, but if the flesh side of skins is treated the hairs will be only partly removed.

A well-known tanner gives the following account with regard to this defect and the means of remedying it:—

After treating the skins, they were placed in layers and left to themselves for some time till the hairs became loose. They were then hung up and allowed to run off every two hours, and after 6—10 hours could be easily and completely depilated in the fulling trough. It was further noticed that leathers treated on the flesh side dried very quickly, and that this circumstance prevented the depilation. In order to remedy this defect, the writer placed the treated and folded skins in a tub full of water. The skins were well swelled and gradually rose above the water, because they increased in volume, and the hair could be removed from all parts of the skin. Skins treated with sodium sulphide are said to have 10·4 per cent. more weight than limed skins.

The tanning in this case must be effected in the following manner: The fibres of such skins have already begun to swell, and therefore do not require those powerful agents, *i. e.*, larger quantities of acids, which sweated skins require. The ordinary tans are sufficient.

The author thinks that the lime will soon be superseded by sodium sulphide, because it is very essential in the summer to hasten the first operations, and also because a better quality of leather is obtained, which latter will henceforth be the watchword of the tanner, for the American hemlock-leather competes very successfully with second-class leathers tanned in Germany, and therefore the author believes that, in order to insure the manufacture of first-class leather, the skins must in the first place be treated with sodium sulphide.

Eitner admits that there are tanners who still object to the use of sodium sulphide in the manufacture of upper-leather, but he thinks that they have not applied it properly, and insisting on their old method, have not considered the slight modifications which have to be made.

Tanners have hitherto been of opinion that skins treated with lime give upper-leathers combining firmness with softness. Eitner does

not dispute this fact, but states that lime removes valuable substances from the skins which sodium sulphide will not do, and he therefore recommends the following method:

The skins are soaked, stretched, and if possible fulled. A very careful stretching is enjoined by the author. The skins are then treated with the above-mentioned mixture of 1 part of sodium sulphide and 3 parts of slaked lime. The quantity of sulphide required for each skin depends on the quality and size of the skin, on the quality of the sodium sulphide, on the larger or smaller degree of softness, also on the quality of the lime mixed with the sulphide, and finally on the hardness of the water used, as a portion of the sodium sulphide is fixed by the constituents of hard water and is thus rendered ineffective.

Certain varieties of lime may contain substances which combine with the sodium sulphide, and in such quantities as to completely neutralize the action of the latter. Taking also into account the various qualities of sodium sulphide, which are often much lowered when the salt is kept for some time in a damp place, or badly packed, it is easy to see that absolutely exact numbers cannot be given in all cases, and that only the skill and experience of the practitioner can determine the proper quantities to be used.

Under normal conditions, *i. e.*, a medium article in strength, size, and softness, medium hard water (10°—20° of hardness), pure lime, good and new sodium sulphide, we require for a piece of

Green bullock's skin	105—175 grams.
Dry " "	123—193 "
Dry kips	88—123 "
Dry calf-skin	35— 53 "

The macerated skins are folded together, their flesh side being inside and their hair side out, and are then placed in a tub and covered over with water. After 12—24 hours the skins are ready for depilation. For the further working of the skins two methods may be employed. In the first the skins after depilation are scraped, which can easily be done, as the flesh side was exposed to the action of the sodium sulphide. The heads are then cut out and the skins eventually shaved. The author here mentions the treatment of leather straps used for machines—a mean between sole and upper-leather. The skins when depilated and shaved are placed in soft water and soaked for 2—3 days, when they are again trimmed. After

being stretched they are soaked in water for a short time and are then ready for tanning.

The solutions must be only very slightly acid; and they may be used more concentrated than usually; the number of tans used must never be below eight. By adding 250—500 grams of bicarbonate of soda the solutions will be kept neutral, or we may add ½—1 kilo. of salt, which, in spite of the acid, will prevent the leather from becoming too hard.

Eitner now returns to the upper-leathers which had been scraped and shaved. The upper-leathers which had been scraped and salted are not swelled to the same extent as in the lime process, still they are in a state suitable for tanning. Before doing this it is advisable to clean them. About 5 kilos. of oat-straw are boiled in 110 litres of water, the liquid cooled, the straw picked out, and the skins placed in this solution. If the dung of birds or dogs has to be used, the solution must be made with cold water and the skins treated in the cold. The skin can now be tanned.

In using the ordinary tans the skins swell too much and become too hard, but with extracts they tan exceedingly well. We must therefore work differently if we employ the usual method of tanning, adding bark. The skins are treated exactly in the above-mentioned manner till the depilating process has been finished, but after this they are once more placed in the same vessel in which they were washed after treatment with sodium sulphide. By placing them in this vessel the greater part of the active sodium sulphide is regained and may then be used for swelling the skins. For new and thin calf skins the solution alone suffices, but for harder qualities of leather more sodium sulphide must be added, using about 35—88 grams for a bullock-skin, 27—53 grams for a kip, and 13—22 grams for a calf-skin. The further operations are, with the exception of the smoothening process, quite in conformity with those used in the lime-swelling process.

The use of sodium sulphide is very essential in the manufacture of deer and kip-leathers. As is well known, it is very difficult to work these skins into leather, as most kinds possess a strong and coarse fibrous texture, and good leathers can be obtained only by the use of good and special means. The skins must in the first place be well soaked and be brought into the ooze as quickly as possible. Where there is no good river water for soaking the skins, soda must be added

to the well water. Sodium sulphide, however, answers better, adding about 17—53 grams to the water. The skins can thus be soaked much more quickly and are then ready for their further operations.

For treating most foreign skins lime alone was found to be insufficient and arsenic had to be used. On adding realgar or orpiment to the lime the sulphur in the ooze combines with the lime to form sulphide of calcium, a substance similar to sulphide of sodium. As the sulphur and not the arsenic acts in this case, and as the latter is very expensive and dangerous, sodium sulphide could be more favorably used. For very hard skins twice the normal quantity of sodium sulphide may be used without fear.

In the manufacture of horse-leather a portion of the skin, viz., the back part, is always tougher than the other parts of the skin, and therefore requires more sodium sulphide. The tanning of these leathers is performed in well-prepared solution, which can afterwards be more concentrated with tannin, as it is very advantageous to strengthen the ooze by adding extracts to it. The use of extracts deserves the highest attention as regards the quality of the leather and the profitable consumption of the tannin materials.

The tanning of pig-skins also belongs to that of upper-leathers. These skins are generally very loose and the large amount of fat they contain renders the process more difficult, as the lime-soap formed can only be partially removed and thus hinders the tanning. By using sodium sulphide this soap is converted into a substance soluble in water.

Manufacturers of morocco-leather have adopted the use of sodium sulphide, because the lime frequently spoils these kinds of leather. The author would like to know whether the wool obtained from these skins treated with sodium sulphide shows the same defects as that of skins treated with lime. He thinks that the former will wash better, as the fat has been removed and does not require a separate treatment with soda, as is the case in the lime process.

With regard to the manufacture of kid-leather, Eitner states that its treatment with sodium sulphide is fully described in No. 13 of "Der Gerber," and that thus the question respecting the use of sodium sulphide is settled for the present in all the branches of the leather industry.

The author in conclusion states that the results of his method depend on the quality of the sodium sulphide used. He recom-